

## CONTRIBUTIONS FROM THE LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA.

## NO. I.

## CORUNDUM,

## ITS ALTERATIONS AND ASSOCIATED MINERALS.

*(Read before the American Philosophical Society, September 19th, 1873.)*

BY F. A. GENTH.

At the meeting of the American Philosophical Society of April 21st, 1871, I have exhibited and described several peculiar crystals of corundum, either wholly or partly altered into other mineral species. The chemical examination of these and many others, which I have since received, has given results and led to conclusions which, in connection with their paragenesis, are of not less interest to the chemist and mineralogist than to the geologist.

My information as to the occurrences of corundum in Europe and Asia is too limited to give a full outline of the same; I shall confine myself therefore, to those of *this* country and shall endeavor to give briefly the most striking geological features under which they have been observed.

The rocks of the Laurentian System contain but very little corundum, and only a few isolated crystals of white, red and blue colors have been found in the granular limestones belonging to this formation. It occurs, for example, associated with spinel, chondrodite, hornblende, graphite and numerous other minerals at Warwick and Amity, in the State of New York; at Newton, Vernon and Franklin in New Jersey.

The largest deposits of corundum known in the world, occur in the chromiferous serpentine or chrysolite formation, and in the rocks immediately adjoining the same. Numerous localities have been developed from Massachusetts to Alabama, and it will always be a very interesting question, by what agencies such enormous quantities of alumina could have been precipitated to form corundum, which, by its subsequent alteration has given rise to many of our most widely distributed minerals and rocks.

The most important corundum deposit in the Eastern States has been discovered by C. T. Jackson,\* at Chester, Mass.; it was subsequently described by C. U. Shepard† and J. L. Smith.‡

It consists of crystalline corundum in a fine scaly chlorite, or of a peculiar mixture of granular and crystallized corundum with magnetite (which is generally titaniferous), intermixed with more or less of a chloritic mineral. The whole deposit traverses two mountains for about four miles, with an average thickness of four feet, and lies in a talcose slate and serpentine between gneiss and mica slate, in the centre of the

\* C. F. Jackson, *Sill. Journ.* [2] XXXIX, 88.† C. U. Shepard—*Sill. Journ.* [2] XL, 112-123; XLII, 421; XLVI, 256.‡ J. L. Smith—*Sill. Journ.* [2] XLII, 83.

Green Mountains. The gneiss contains *no* corundum ; the talcose rock, however, has grains of emery, corundum and magnetite disseminated through the whole mass ; a vein of oligoclase (so-called indianite) many inches in thickness with small particles of corundum diffused through it, runs for many rods through the chloritic rock.

The corundum is generally in small brownish crystals, or very fine grains ; the variety sapphire is sometimes met with in bi-pyramidal crystals ; pinkish margarite, diaspore and corundophilite frequently invest the corundum or emery, which is also associated with tourmaline, cyanite chloritoid, ilmenite, rutile, etc. With the oligoclase occurs a dark-green variety of biotite.

The views of Jackson, endorsed by Shepard, that the Chester (Mass.) emery was a distinct mineral species and that it had the composition of hercynite,  $\text{FeO}$ ,  $\text{Al}_2\text{O}_3$ , has already been refuted by J. L. Smith.

I will here mention a few other New England localities of corundum, although they may not belong to the chromiferous serpentine region.

J. H. Adams\* observed it in small quantity and rarely in situ at Pelham, Mass., in flattened masses of a brownish-black mica (Biotite, Shepard†) containing nodules of corundophilite (Vermiculite, Shepard†) inclosing white and sapphire-blue corundum.

At Litchfield, Conn., it is found in balls of cyanite, constantly associated with talc and diaspore (Shepard†) ; and at Norwich, Conn., in small crystals of sapphire-blue color, completely surrounded by fibrolite (Shepard†).

In Pennsylvania corundum is found in many localities between the serpentine and the granitic and gneissoid rocks, commencing near the Blue Hill, in Upper Providence Township, and extending for about five miles to near Rockdale, Middletown Township, Delaware County ; and again appearing near Unionville, in Newlin Township, Chester County.

At Mineral Hill and the Black Horse, near Media, Delaware County, occurs a feldspathic rock, consisting of a triclinic feldspar of a yellowish-white or white color and granular structure, and showing striation very distinctly on some of the cleavage planes. A great part of it is already changed into kaolinite. It appears to be free from quartz, but disseminated through the mass are crystals of corundum more or less altered into fibrolite and a micaceous mineral, probably damourite ; many loose crystals of corundum are found in the soil.

At Unionville, Chester County, crystals of corundum have been frequently met with in the soil, and even large boulders are not of unusual occurrence ; a little over one year ago, the bed from which these evidently came was discovered. At the time of my visit I could see a mass of almost solid corundum about thirty feet in length, from five to ten feet in thickness, with a depth of about fifteen feet. The corundum is of a granular structure, a brownish-grey color, and like the crystals which

\* J. H. Adams—Sill. Journ. [2] XLIX, 272.

† C. U. Shepard—Sill. Journ. [3] IV, 179-180.

were found in the soil, shows a gradual change into several other minerals. The species which have been observed at this locality are diaspore, gibbsite (Seal\*), damourite, margarite, soda-margarite, euphyllite, zoisite, tourmaline, chlorite, lesleyite and pattersonite.

About one mile from Unionville on the road to Kennett Square, corundum crystals are found imbedded in granular albite, together with euphyllite and tourmaline; it is also associated with black spinel, chlorite, talc, actinolite, etc.

Of the occurrence of corundum in Virginia, I have only one indication in the shape of a piece of a pebble from the neighborhood of Staunton, Augusta County, which principally consists, as shown by a qualitative analysis, of chloritoid with minute particles of corundum disseminated through it and a mass of damourite attached to, or passing in small seams through the chloritoid.

By far the most numerous localities of corundum, and many of them of great scientific interest, are found in North Carolina. The most Eastern occurrence which appear to belong to this formation, is on the lands of the Widow McChristian near Friendship, in Guilford County, and forms part of the great titaniferous iron ore belt of that State.

The corundum, of which only some surface specimens have been found, is a *true emery*, consisting of granular corundum, mechanically mixed with magnetic iron. It is associated with a chloritic mineral, generally changed into a white micaceous one by weathering, ilmenite and small quantities of chromite. Two samples gave me as follows:

Corundum.....	= 52.24	—	44.86
Magnetite.....	= 42.77	—	46.29
Silicates, etc.....	= 4.99	—	8.85

The whole bed lies in granitic rocks and there is no sign of serpentine or chrysolite in the neighborhood; the presence of chromite, however, and of the chlorites, closely resembling those of the serpentine range, makes it probable that the belt belongs to the latter.

Science is much indebted to Rev. C. D. Smith, to whom the credit is due, for the discovery of the corundum belt which stretches with occasional interruptions in a southwesterly direction from Madison County, North Carolina, through Georgia into Tallapoosa County, Alabama, a distance of at least 250 miles. Of this, C. U. Shepard† gave, a short time ago, an elaborate description. The first large mass was found in 1847, on the French Broad River, three miles below Marshall in Madison (then Buncombe) County. It was of a dark-blue color and was associated with chlorite and margarite. The bed from which this and several smaller masses occurring in loose boulders have come, has never been found; but judging by the associated minerals there can be no doubt that it came from the great chrysolitic belt. I believe that I was the first

\* T. F. Seal—Sill. Journ. [2] XI. 267.

† C. U. Shepard—Sill. Journ. [3] IV, 109 to 114 and 175 to 180.

to suggest, that the chromiferous and nickeliferous serpentines and talc slates owe their existence to the decomposition of chrysolite rocks;\* an opinion which has since been proved to be correct for those rocks wherever they have been found; and lately by very careful examinations of serpentines and serpentine-like rocks made by Richard von Drasche.†

C. U. Shepard‡ endeavors to show that the real composition of these rocks is not that of chrysolite but of villarsite. I have, therefore, requested Mr. Th. M. Chatard to analyze a specimen from the Culsagee Mine or Corundum Hill, near Franklin, Macon County, North Carolina, and for comparison, add my old analysis of a variety from Webster, Jackson County, North Carolina.

	Chatard.	Genth.
SiO <sub>2</sub> .....	= 41.58	41.89
Al <sub>2</sub> O <sub>3</sub> .....	= 0.14	trace
FeO.....	= 7.49	7.39
NiO (tr Co & Mn).....	= 0.34	0.35
MgO.....	= 49.28	49.13
CaO.....	= 0.11	0.06
Ignition.....	= 1.72	0.82
Chromic iron, etc.....	= —	0.58
	<hr/>	<hr/>
	100.66	100.22

Villarsite is only an intermediate product of decomposition between chrysolite and serpentine. A rock, which approaches the latter mixed with a triclinic feldspar, occurs under similar circumstances as the Cullakenee or Buck Creek Mine in Clay County.

An analysis of a specimen which, however, was not quite pure, gave me:

SiO <sub>2</sub> (by difference).....	= 35.19
Al <sub>2</sub> O <sub>3</sub> .....	= 0.64
FeO.....	= 9.70
MgO.....	= 40.99
Ignition.....	= 13.48
	<hr/>
	100.00

The outcrop of the Culsagee Mine extends over thirty acres and the strata developed there are, according to Prof. Shepard (loc. cit.):

1. Chrysolite rock, somewhat mixed with anthophyllite;
2. a layer of micaceous rock;
3. a seam of chalcedony;
4. a stratum of chloritic rock (ripidolite);
5. the same through which the corundum is irregularly diffused, sometimes in narrow veins or widening out to several feet."

\* F. A. Genth—Sill. Journ. [2] XXXIII, 202.

† R. von Drasche, in G. Tschermak's Mineralogische Mittheilungen 1571, 1.

‡ C. U. Shepard—Sill. Journ. [3] IV, 112.



“Narrow veins containing, besides the chlorite and corundum, a dark-blackish-green spinel, more or less mingled with black tourmaline, traverse the layers 4 and 5 in various directions.”

From Col. Jos. Willcox I have obtained some additional information. He states that the chlorite schist is much decomposed even to a depth of fifty or sixty feet, and the corundum in the same easily falls into fragments. The chlorite schist strikes northeast and southwest. At right angles to it a vein of chlorite several feet wide has been uncovered, which contains the large crystals of corundum, which also fall readily into fragments. A small vein of much decomposed albite, containing small crystals of corundum, passes through the chlorite. At the same place small crystals of corundum are occasionally found in black tourmaline. Associated with the minerals already named are actinolite, asbestos talc, etc.

From Prof. Shepard's paper and the private communications of Rev. C. D. Smith and Col. Jos. Willcox, I gather the following information with reference to the Cullakane or Buck Creek and the Shooting Creek localities, both in Clay County.

About twenty miles southwest from the Culsagee Mine near Buck Creek, in Clay County, is the so-called Cullakenee Mine; the outcrop of the chrysolitic rock covering an area of about 300 acres. Corundum is here found in boulders in many places. The chrysolite contains the usual associates of the serpentine localities, such as actinolite, pierolite, etc., and is already partly changed into serpentine. Near the middle of this chrysolite bed is an outcrop of a very peculiar rock, resembling the omphacite of Hof, Bavaria, and consisting of green smaragdite,\* a white triclinic feldspar and highly colored grains of ruby, sometimes also intermixed with small quantities of cyanite and chromite. The corundum at the Cullakenee Mine is generally of a grayish-white, or pale ash-gray color, rarely with specks of sapphire through it; sometimes also of a beautiful pink color, and is associated with andesite, zoisite, margarite, hornblende, and rarely with chlorite, spinel and tourmaline. A peculiar white or grayish-white scaly mineral in flattened masses with a nucleus of corundum rarely occurs, which is described under the name willcoxite.

About ten miles southwest of Cullakenee, near Shooting Creek, Clay County, corundum is again met with, and for five or six miles from this place extending into Towns County, Georgia, it is found at many places associated with chlorite, and probably smaragdite; the chrysolite lying between beds of hornblendic gneiss.

The Rabun County, Georgia, locality much resembles that of the Culsagee Mine near Franklin, North Carolina, and the corundum which I have seen from there can hardly be distinguished from the latter.

Near Gainesville, Hall County, Georgia, occurs a very peculiar variety of corundum. For the information about this locality and the specimens

\* See below.

I am indebted to Rev. C. D. Smith. He states that soapstone appears to be the leading rock. Amongst the specimens were several which appeared to be talc slates of a pale greenish-white color, but, which by an analysis of Dr. Geo. A. Koenig, were proved to be a true chlorite slate. He found :

SiO <sub>2</sub> .....	= 30.33
Al <sub>2</sub> O <sub>3</sub> .....	= 20.90
Fe <sub>2</sub> O <sub>3</sub> .....	= 4.00
FeO.....	= 4.11
MgO.....	= 27.79
Ignition.....	= 12.63
	99.75

The corundum occurs as a nucleus in irregular kidney-shaped masses of margarite, or with a peculiar earthy mineral of a color between isabel and flesh-red, and frequently intersected by veins of a fine scaly or massive margarite. I shall give the analyses of both in the mineralogical part of this paper. There are found at the same locality dark-green foliated chlorite, actinolite, asbestos and tourmaline.

It remains to say a few words with reference to the occurrence of corundum near Dudleyville, Alabama. For specimens from this locality I am indebted to Rev. C. D. Smith, of Franklin, North Carolina, and to Prof. Eugene A. Smith, of Tuscaloosa, Alabama. From these it is evident that the deposit is a repetition of those already discussed; chrysolite rocks to a great extent changed into serpentine and even talc, with asbestos, chlorite and tourmaline; the corundum is associated with spinel, margarite and dudleyite, a mineral resulting from the alteration of the latter.

Very similar to these occurrences of corundum in our great chromiferous serpentine region are those in the Ural, described by G. Rose.\* At Mramorsk, on the west side of a marble quarry is one of leekgreen serpentine, and at another quarry a greenish-black chlorite schist with fine grained emery intermixed. The chlorite schist contains little veins or patches filled with a rose-red or reddish-brown mineral, foliated chlorite, a white micaceous mineral and yellowish-gray granular zoisite. Some of the veins contain diaspore and chloritoid. The marble quarry at Kassoibrod has on its western side chloritic schist; on the eastern side granite. In the chlorite schist was found a crystal of blue corundum, a six-sided prism with basal plane on which was observed white star-like opalescence. Generally there is very little corundum present; the associations of which are tourmaline, chlorite, etc.

J. L. Smith,† in his very important paper on emery, relates the occurrences of emery, corundum and associated minerals in Asia Minor and the Grecian Archipelago. According to his observations the emery is

\* G. Rose Reise nach dem Ural, etc., 151, 248, 256.

† J. L. Smith--Silh. Journ. [2] X, 355 ff. and XI, 53 ff.

always imbedded in marble or granular limestone when found in situ ; the marble lies upon mica slate, gneiss or granite. The minerals associated with the emery and corundum are : diaspore, gibbsite, zinc-spinel, pholerite, ephesite, margarite, mica (muscovite?) chloritoid, black tourmaline, chlorite, magnetite, hematite, limonite, rutile, ilmenite and titaniferous iron.

This represents very much the list of the species which occur with the corundum and emery of our chromiferous serpentine region and it is not improbable that the emery beds in Asia Minor and Greece are of analogous age.

I have now to speak of the occurrence of corundum or of minerals resulting from its alteration in a series of slates considered by E. Emmons\* as belonging to his Taconic System.

The first corundum in them was discovered in 1852, by Dr. C. L. Hunter,† in Gaston County ; it occurs at Crowder's Mountain and Clubb's Mountain ; and it has lately been discovered under similar circumstances in Rutherford County. It is associated with rutile, cyanite, damourite, lazulite, pyrophyllite, gold and quartz.

There are reasons to believe that the pyrophyllite beds in Orange, Chatham, Moore and Montgomery Counties are analogous to the corundiferous strata of Gaston County ; and the same appears to be true for those at Graves Mountain, Lincoln County, Georgia.

There are two occurrences of corundum in cyanite in the gneissoic rocks at Swannanoa Gap, Buncombe County, and in Wilkes County, North Carolina ; neither of which seem to have any connection with the serpentine belt.

I have yet to mention the occurrence of corundum in Laurens District, South Carolina, which is probably in mica slates. All the specimens which I have seen from this locality are rough bipyramidal crystals from one to three inches in length and from one-fourth to one inch in thickness. They are all more or less altered. Most of them are coated with a micaceous mineral into which many of the crystals are completely converted.

I shall not dwell upon the crystals of corundum, ruby and sapphire which are frequently met with in the heavy sands of gold washings as they occur in too minute quantities to have any bearing upon the principal questions which forms the subject of this investigation.

After thus giving a brief outline of the geological features of the occurrence of corundum, I shall now enter upon the consideration of the minerals which are found in association with the same, but will first make a few remarks with reference to the chemical analyses which are embraced in this paper.

The greatest pains were taken to select the very best and purest material ; and all the small fragments, before being reduced to powder, were

\* Ebenezer Emmons, Geol. Report of the Midland Counties of North Carolina, 1856.

† C. L. Hunter—Sill, Journ. [2] XV, 373.

repeatedly examined with a powerful magnifying glass, until the material for analysis was as clean as it was possible to obtain it. This plan was always strictly adhered to, except in a few cases where it was an impossibility to obtain perfectly pure material, but where an approximation was still desirable to identify the species.

The finely powdered minerals were then dried under an exsiccator, over sulphuric acid. As very few of the species analyzed could be decomposed by acids, they had to be fused with sodic carbonate to render them soluble. For the alcalies, the mineral was in a few cases decomposed by fluohydric acid, generally, however, by J. L. Smith's very accurate and convenient method.

The mass of the sodium fusion was then *completely* disintegrated by water, and the whole dissolved in very dilute chlorhydric acid. If the decomposition of the silicates was *complete* and *no appreciable quantity of corundum was mechanically mixed with the mineral*, the solution in dilute acid was perfect, and rarely only a few flakes of silicic acid separated, which were easily distinguished from the heavy, hard, sandy corundum. Both (if both were present) were filtered, washed, dried, ignited and weighed; the silicic acid extracted by a dilute solution of potassic hydrate. After washing out with boiling water, to which towards the end of the washing, a few drops of chlorhydric acid was added, the corundum was weighed, then rendered soluble by fusion with potassic hydric sulphate, from the solution of which the pure alumina was precipitated as usual.

From the fusion for the alkali determination, the residue after extraction by boiling water was treated in a similar manner. The fusion with sodic carbonate acts more powerfully upon corundum, but unfortunately even the fusion of corundum with calcic carbonate and ammonic chloride, renders such a quantity of corundum soluble, that this method can not be used for a quantitative determination of the same.

The analyses were then conducted as usual, the alumina was separated together with ferric oxide by ammonic hydrate and boiling of the ammonical magma, until it had a neutral or even acid reaction. After filtering and washing they were re-dissolved and re-precipitated, and this operation generally repeated three or four times. The ferric oxide in the alumina was determined after the conversion of both into sulphates and its reduction by zinc, by titration with potassic permanganate.

The amount of ferrous oxide was *always* ascertained by dissolving the minerals in a sealed tube under pressure with dilute sulphuric acid, and subsequent determination with potassic permanganate.

Some apparently quite pure spinels left when treated in this manner a small quantity of a sandy powder, which proved to be corundum. I had hoped that by this method an accurate determination of corundum, mechanically mixed with other minerals, could be obtained, but I found that dilute sulphuric acid under such circumstances dissolves corundum,

reduced to an impalpable powder, with tolerable ease. We have therefore no means to determine the quantity of corundum, which is *mechanically* mixed with another mineral. This is unfortunate, as it will leave us in doubt about the true constitution of some varieties of lesleyite and of ephesite.

Magnesia was always precipitated by ammoniac phosphate. Of the alcalies the potassic sodic and lithic chlorides were weighed together, then the potassium were separated and weighed as potassic platinochloride, and in the filtrate, after the removal of the excess of the platinum and the conversion of the alcalies into sulphates, the quantities of sodium and lithium were determined by indirect analysis. As however, in many cases the quantity of lithia, indicated by the spectroscope, was only small, very few such determinations have been made.

These being the more important points with reference to the modes of analysis, I shall now proceed with the description of the minerals.

#### 1. CORUNDUM.

As it would require unnecessary repetition, I shall not at present describe the numerous varieties of corundum, but shall mention their peculiarities, when treating of the minerals associated with them, and of their relation to each other.

#### 2. SPINEL.

Corundum altered into spinel occurs at several localities.

*a.* The most interesting variety comes from Hindostan, and was found in a lot of corundum crystals, purchased by Messrs. S. S. White & Co., to whom I am indebted for specimens.

The surface of these crystals or crystalline masses is rough, and to many of them reddish orthoclase and a dark mica are attached, showing their matrix to have been granite. Some pieces of the corundum contain also small scales of reddish-white margarite. The crystals are too indistinct for measurement, but the basal plane and one or two pyramids can be observed. Many are completely altered, most of them, however, show that the alteration began at the surface and has irregularly penetrated the crystals towards the centre, often leaving a nucleus of brownish-gray cleavable corundum, or patches of the same irregularly distributed through the mass. Most of the crystals are from a half an inch to about two inches in size, rarely larger.

The spinel, which is the result of this alteration, has a black color, granular crystalline structure and a submetallic to vitreous lustre. Its powder is gray; it is slightly magnetic.—H.—S. Sp. Gr.—4.208.

*b.* In the shaft on the road from Unionville to Kennett Square, associated with granular grayish-white talc and greenish actinolite occurs intimately mixed with chlorite, a black granular mineral of vitreous lustre and a hardness superior to that of quartz. It was impossible to obtain it for analysis in a state of purity, but sufficiently so to prove it to be spinel.

*c.* The vein of spinel passing through the chlorite at the Culsagee Mine,



North Carolina, has already been noticed above. The spinel is generally massive, coarsely to finely granular; also met with in octahedral crystals with dodecahedral planes; the latter often indicated only by striation. The crystals are often imperfect and cavernous, and mostly altered on the surface, being covered with a varnish-like coating of a brownish-gray mineral of vitreous lustre. The interior of the crystals like the fresh fracture of the unaltered massive spinel is black. The spinel contains, sometimes, grains of a reddish-brown rutile, and is always more or less intermixed with grains of corundum and chlorite, the latter frequently radiating from it. One specimen in the University collection is a mass of chlorite, radiating from nucleus consisting of a mixture of spinel and corundum.

*d.* Another variety of spinel from the same locality, of which, however, I found only a single specimen, resembles G. Rose's *chlorospinel* from Slatoust, and is found in deep leek-green or greenish-black octahedra with deeply striated dodecahedral planes or in granular masses of the same color; it is associated with a pale green foliated chlorite and white corundum. The spinel is often imbedded in the foliæ of the chlorite and not unfrequently contains particles of corundum in its centre. Its powder is pale grayish-green.

*e.* The collection of Col. Jos. Willcox contains a specimen from the same locality which evidently was once a corundum crystal. It measures about two and a-half inches in diameter and its outlines indicate its origin. It now consists of a nucleus of black spinel with a mantle of chlorite.

*f.* At the Cullakenee Mine spinel is of rare occurrence. I have seen only one piece in which a black variety in grains and octahedral crystals is disseminated through dark green foliated chlorite.

*g.* At Dudleyville, Tallapoosa County, Alabama, black spinel surrounding patches of yellowish-white cleavable corundum occurs in chlorite.

*h.* In connection with these observations it is worthy of notice that a variety of spinel, gahnite, in association with the corundum of Gumuch-Dagh in Asia Minor was discovered by J. L. Smith (loc. cit.).

The following analyses were made:

*a*1 and 2, from Hindostan, by myself.

*b*, from Unionville, by Dr. G. A. Koenig.

*c*1, fine-grained from Culsagee, by Dr. Koenig.

*c*2, coarser grained from Culsagee, by Dr. Koenig.

*d*, coarse-grained and crystallized dark-green from Culsagee, by myself

Sp. Gr.	<i>a</i> 1	<i>a</i> 2	Mean.	<i>b</i>	<i>c</i> 1	<i>c</i> 2	<i>d</i>
Al <sub>2</sub> O <sub>3</sub>	48.87	48.10	48.49	54.61	60.03	62.38	68.08
Fe <sub>2</sub> O <sub>3</sub>	17.30	18.17	17.73	4.10	9.49	7.79	1.75
Cr <sub>2</sub> O <sub>3</sub>	—	—	—	—	3.23	1.81	trace.
FeO	23.53	23.25	23.39	10.67	9.33	11.89	11.02
MnO	trace.	trace.	—	—	—	—	trace.
MgO	6.86	6.66	6.76	13.83	16.74	14.98	19.29
SiO <sub>2</sub>	—	—	—	1.26	1.14	1.56	CuO = 0.11
Corundum	=4.31	4.31	4.31	16.24	—	—	NiO = 0.24
	100.87	100.49	100.68	100.71	99.96	100.41	100.49



Neither specimen showed on examination with a magnifying glass any corundum, but both *b* and *c1* and 2 contained small quantities of chlorite. I shall leave out the analysis *b*, which was made with material of not sufficient purity to base any calculation upon the results, but only for the purpose of ascertaining the character of the black mineral. This analysis, however, established the very important fact of the mechanical admixture of corundum. Taking into consideration the analyses of *a* and *c1* and 2, and *d*, we arrive at the following data :

*a*. The oxygen in the mean results of the two analyses of the spinel from Hindostan is, in the sesquioxides, 4.22 per cent. in excess over that required by the formula  $RO, R_2O_3$ , showing that besides the 4.31 per cent. of corundum, which was not dissolved by dilute sulphuric acid, 9.05 per cent. had gone into solution, and that the most carefully selected material still contained a mechanical admixture of 13.36 per cent. of corundum. The composition of the pure spinel, together with that of the pure spinels from Culsagee, I shall give below.

*c1*. After deducting for 1.14 per cent. of  $SiO_2$ , 0.93  $Al_2O_3$ , 0.09  $Fe_2O_3$ , 0.22 FeO and 1.18 MgO, corresponding with the foliated chlorite from this locality, the oxygen ratio between RO and  $R_2O_3$  required by the spinel formula is 6.67 per cent. in excess in the sesquioxides, representing an admixture of 14.74 per cent. of corundum.

*c2*. The 1.56 per cent. of  $SiO_2$  require, for making the foliated chlorite associated with the spinel, 1.28  $Al_2O_3$ , 0.14  $Fe_2O_3$ , 0.32 FeO and 1.61 MgO, which being deducted, leaves the oxygen ratio between RO and  $R_2O_3$  = 7.92 : 31.34, being for the sesquioxides 7.58 per cent. more than that required by RO,  $R_2O_3$ ; this corresponds with a mechanical admixture of 16.27 per cent. of corundum.

*d*. The decomposition by dilute sulphuric acid gave 0.73 per cent. of silica and a trace of corundum, which were deducted from the quantity taken for analysis. The oxygen ratio 1 : 3.15 is nearly that of spinel. The excess of 1.57 per cent. of oxygen would represent an admixture of 3.37 per cent. of corundum.

After deducting these mechanical admixtures, the composition of the pure minerals is represented by the following :

	Hindostan <i>a</i> .	Culsagee <i>c1</i> .	Culsagee <i>c2</i> .	Culsagee <i>d</i> .
$Al_2O_3$	45.17	54.32	56.58	66.63
$Cr_2O_3$	—	3.96	2.28	trace.
$Fe_2O_3$	20.30	11.51	9.66	1.80
FeO	26.79	11.16	14.60	11.35
MgO	7.74	19.05	16.88	19.86
CuO	—	—	—	0.11
NiO	—	—	—	0.25

These analyses show that the spinel, pseudomorphous after corundum, from Hindostan, and the green spinel from Culsagee *d*, are mixtures of the spinel varieties *pleonaste* and *hercynite*, whilst the spinels from Culsagee *c* (1 and *b*) contain besides an admixture of the variety *picotite*.

The spinels from Unionville, Pennsylvania, and Dudleyville, Alabama, contain only traces of chromic oxide and are probably mixtures of pleonaste and hereynite.

### 3. DIASPORE.

Diaspore has been observed in many places as the result of the hydration of corundum, but I am not aware that ever a real pseudomorph has been met with.

J. L. Smith (loc. cit.) has made the very important observation that all the corundum, which he had examined, contained water in variable quantities from 0.68 to 3.74 per cent., but states that the more careful and repeated examination showed the absence of diaspore or any other hydrate of alumina. May it not be that the diaspore is so very minutely distributed through the corundum, that even the best microscopic, or other examination could not detect it, as I just have shown with regard to the admixture of corundum in spinel?—On page 58 he makes the following remark: “*Yet of all the specimens collected, none offer so much interest as those of diaspore imbedded in the corundum; here we see the two minerals, without being able, in many places to distinguish the line of separation, so imperceptible is the gradation. After what has been said in respect to corundum, it is not astonishing to see this connection of alumina more or less hydrated, with a hydrate of alumina of definite composition.*”

The diaspore from the different localities has been so fully described that I have but little to add.

With the exception of the locality of Chester, Mass., where it had been found in considerable quantity and of great beauty, diaspore is a rare mineral in this country. Most beautiful crystals of it were found at the Unionville, Pa. locality, by Dr. Isaac Lea,\* who gave a description of them before the Academy of Natural Science.

J. C. Trautwine† first noticed this mineral in cavities of the massive corundum from the Culsagee Mine, North Carolina, where it occurs in very minute but beautiful acicular crystals of the usual forms. Only one or two specimens have thus far been discovered.

I have not been able to detect it at any other of the North Carolina, South Carolina, Georgia or Alabama corundum localities.

### 4. BEAUXITE.

This hydrate of alumina, generally mixed with a considerable quantity of ferric hydrate and a hydrous aluminous silicate, occurs in considerable quantities in the southern part of France; it incloses occasionally grains of corundum.

T. S. Hunt's‡ remarks about this interesting fact, are as follows: “By intense heat this substance (beauxite) is converted into crystalline

\*Proceedings of the Academy Natural Sciences, April 9, 1837.

†Journ. Franklin Institute, XCIV. 7,

‡T. S. Hunt, Sil. Journ. [2] xxxii. 288.

“*corundum resembling emery in its physical characters, but the presence of grains of corundum in the hydrated mineral seems to show that the transformation may take place at ordinary temperature.*” I do not know of a single instance, in which corundum could have been eliminated under such circumstances from the hydrate; on the contrary, the presence of grains of corundum in the beauxite prove pretty conclusively, that the latter results from the hydration of corundum, and that the grains which have been found are remnants not yet converted. The same may be said of the inclosing argillaceous matter, that it is the result of the alteration of corundum.

#### 5. GIBBSITE.

This very rare hydrate of alumina has been so far as I can discover, only twice noticed in contact with corundum, evidently resulting from its hydration, first at Gumuch Dag, Asia Minor, by J. L. Smith (loc. cit.) who observed it as forming an external coating of a crystal of corundum, and also in the form of a hexagonal prism. The latter is very probably a pseudomorph of gibbsite after corundum. The second locality is at Unionville, Pa., where T. F. Seal\* found it as a thin coating of small mamillary incrustations on the albite rock. (The other coatings on corundum crystals, of which he speaks, are evidently not gibbsite, but margarite, as I shall show in the sequel.)

#### 6. QUARTZ.

Sillem† mentions that quartz occurs pseudomorphous after corundum.

I have never observed this pseudomorph, and have not seen the original paper, I therefore merely mention the fact for the sake of completeness.

#### 7. OPAL.

It is perhaps worthy of notice that I have observed the variety hyalite in connection with corundum and minerals resulting from its alteration. At the Culsagee Mine it is rarely found in beautiful colorless and white botryoidal incrustation upon foliated chlorite, and also upon corundum. From Dudleyville, Alabama, I have one specimen, on which it occurs as a brownish-white botryoidal incrustation upon blue cleavable corundum.

One of the pseudomorphous fibrolite crystals, from Mineral Hill, Delaware County, Pa., has a slight coating of an amorphous botryoidal vitreous mineral, which appears to be hyalite.

#### 8. SMARAGDITE (?) (KOKSCHAROFFITE).

I have already mentioned the peculiar rock formed by Smaragdite (?), a feldspathic mineral, and grains of pink or even deep ruby corundum, and sometimes chromite disseminated through the mass, which occurs at the Cullakenee Mine.

The grains of smaragdite (?) are very indistinct in form, but frequently show an obtuse angle like that of an amphibole. The color is from

\* T. F. Seal. Sill. Journ. [2] xi, 267.

† Sillem, Leonhard & Bronn's Jahrbuch—1851, 385.

emerald to grass-green, and passing into grayish-green to greenish-gray.  $H = 5.5$ . Sp. Gr. of the grass-green variety = 3.120.

B. B. it melts easily to a greenish glass, whilst the outer flame is colored yellow.

A sample of the grass-green mineral, selected with great care and apparently *free from feldspar*, was analyzed by Mr. Thos. M. Chatard, who found :

SiO <sub>2</sub>	=	45.14	contains oxygen	24.07		=2.06
Al <sub>2</sub> O <sub>3</sub>	=	17.59	"	"	8.20	} = 8.45 = 0.72
Cr <sub>2</sub> O <sub>3</sub>	=	0.79	"	"	0.25	
FeO	=	3.45	"	"	0.77	} = 11.7 = 1
NiO	=	0.21	"	"	0.04	
MgO	=	16.69	"	"	6.68	} = 11.7 = 1
CaO	=	12.51	"	"	3.57	
Na <sub>2</sub> O	=	2.25	"	"	0.58	} = 11.7 = 1
K <sub>2</sub> O	=	0.36	"	"	0.06	
Ignition	=	1.34				

100.33

This gives very nearly the atomic ratio of RO\* : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> = 1 : 0.25 : 1 = 4 : 1 : 4, corresponding to the formula : 4RO, 3SiO<sub>2</sub> + R<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>.

It will be observed that this agrees exactly with the composition of Kokscharoffite, and that it has no resemblance to arfvedsonite, with which it has been placed by C. U. Shepard (*loc. cit.*) as chromarfvedsonite. At some corundum localities we find that other varieties of amphibole are associated with corundum, or even penetrate into the mass of the same.

A black or brownish-black hornblende frequently occurs in the andesite of Cullakenee, Clay County, North Carolina, and a dark green almost black variety, resembling actinolite is found, often associated with zoisite, with and in the corundum of the same locality ; also with the corundum at Shooting Creek in the same County, and rarely at the Culsagee Mine.

#### 9. ZOISITE.

In the Ural, at Mramorsk, zoisite has been observed by G. Rose (*loc. cit.*) as an associate of corundum. B. Silliman† described it under the name *unionite* as occurring in company with corundum, tourmaline and euphyllite at Unionville, Pennsylvania, but the best locality of it is the Cullakenee Mine, in Clay County, North Carolina. Here it occurs in crystals, but usually in compact columnar and easily cleavable masses. Its color is from grayish to greenish and brownish-white. Many of the specimens show distinctly that it is the result of the alteration of corundum. The pink corundum is often surrounded by a thin coating of

\*Including R<sub>2</sub>O in this and all subsequent analyses.

† B. Silliman 2] VIII, 384.

white zoisite. The University collection contains some remarkable specimens.

One forms a narrow vein of cleavable pink corundum in grayish-green hornblende. Between the corundum and the hornblende is a thin lining of zoisite, which becomes thicker and thicker and soon occupies the whole vein, first in compact, then in cleavable columnar masses, the corundum having entirely disappeared. Another piece of blueish-gray corundum is on one side altered into columnar brownish-white and white zoisite, whilst the interior is to a great extent changed into margarite. Many of the other pieces show nuclei of unaltered corundum disseminated through the mass of zoisite.

The following were analyzed :

*a*, slightly greenish-white cleavable zoisite, the result of the alteration of pink corundum, by Dr. Koenig.

*b*, white, slightly grayish columnar zoisite, resulting from blueish-gray corundum, nuclei of which were still visible, by myself.

*c*, for comparison I give the analysis of the zoisite from Unionville, by G. J. Brush\* (Silliman's Unionite).

Sp. Gr.	=	<i>a</i> .	<i>b</i> 1.	<i>b</i> 2.	<i>c</i> .
SiO <sub>2</sub>	=	3.286		3.224	3.299
Al <sub>2</sub> O <sub>3</sub>	=	40.70	39.43	39.86	40.61
Fe <sub>2</sub> O <sub>3</sub>	=	33.86	} 34.92	33.84	33.44
MnO	=	0.81		1.62	0.49
MgO	=	trace.		trace.	—
CaO	=	0.22		0.18	trace.
Na <sub>2</sub> O (trace Li <sub>2</sub> O)	=	24.05		23.82	24.13
K <sub>2</sub> O	=	not det'd		0.22	—
Ignition	=	.. ..		0.09	—
		0.63		0.78	2.22
		100.27		100.41	100.89

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> are as follows :

<i>a</i>	=	6.96	: 16.02	: 21.71	= 1	: 2.30	: 3.12
<i>b</i>	=	6.94	: 16.25	: 21.26	= 1	: 2.34	: 3.06
<i>c</i>	=	6.89	: 15.74	: 21.66	= 1	: 2.28	: 3.14

All these analyses of the zoisite associated with corundum show a slight excess of alumina, if we take the ratio of 1 : 2 : 3 as representing the composition of zoisite. If this is owing to a small admixture of unaltered corundum, the three specimens analyzed would contain : *a* 4.50 per cent., *b* 5.0 per cent., and *c* 4.21 per cent. of it.

#### 10. FELDSPARS.

Many varieties of feldspar occur with corundum under circumstances which are of the greatest scientific interest.

*a*. A white, grayish and reddish variety of *anorthite* called *indianite*

\* G. J. Brush, Sill. Jour. [2] XXVI, 69.

by Count Bourmon, is the matrix of corundum in the Carnatic. Associated minerals are cyanite and garnet. It has been analyzed already by Cheucvix more than 70 years ago, and lately again by G. J. Brush\* with almost identical results, if we except the small quantity of soda which the former had overlooked. Oxygen ratio of  $RO\dagger : Al_2O_3 : SiO_2 = 1 : 3 : 4$ .

b. A snow-white massive granular feldspar also occurs as the matrix of corundum at Barsowskoi, near Kyschtinsk in the Ural, where G. Rose discovered it, who finding it different in composition gave it the name of *barsowite*. Oxygen ratio of  $CaO : Al_2O_3 : SiO_2 = 1 : 3 : 5$ . I have seen only one specimen in which the grayish corundum in dipyrnidal crystals was disseminated through the feldspathic mineral. In fracturing a piece the corundum crystals left a smooth impression upon the barsowite, as if they were already hard when the latter was still in a plastic condition.

e. A snow-white or blueish-white cleavable variety of feldspar showing a fine striation upon the cleavage planes, is found associated with a greenish-black hornblende with a distinct cleavage angle of  $124^\circ$ , is found at the Cullakenee corundum locality, but I have not been able to detect corundum in any of the *cleavable* specimens, which I had for examination. See analysis below. (a).

A granular and very compact variety with crystals of corundum disseminated through it, is found at the same locality. In a fresh fracture the corundum is hardly distinguishable, except by its somewhat grayer color. In weathered specimens the corundum crystals, some of nearly one inch in diameter, stand out in bold relief. They are very rough, as if they were eaten, and in many of them a micaceous mineral, damourite probably, is associated with them, which not only coats the outside but penetrates even to the centre of the crystals. I received this variety too late for chemical analysis.

Together with massive gray corundum, partly altered into zoisite, is rarely found at the same locality a white granular variety of feldspar, much of the appearance of sugar, but pretty tough. It seems to have been the result of the alteration of corundum. The analysis is given below (b).

d. Another fine-grained and very friable variety from Cullakenee has much of the appearance of the oligoclase (indianite) of Chester, Massachusetts. It is distinguished from the Chester mineral by a dissemination through the whole mass of fine grains or crystals of hornblende, whilst the latter contains biotite in their place. It has not been analyzed.

I have already mentioned the triclinic feldspar, forming with smaragdite and red corundum, the peculiar rock which so nearly resembles that from Hof in Bavaria. I have not been able to obtain it in a state of sufficient purity for analysis.

\* Dana's Descriptive Mineralogy. 1838, 339.

†  $RO = 1.6 Na_2O + 5.6 CaO$ .



From this locality I have the analyses of the cleavable snow-white variety (*a*) by Dr. Koenig; and of the fine-grained, like sugar, probably resulting from the alteration of corundum, by Mr. Thos. M. Chatard (*b*) They found:

	<i>a.</i>				<i>b.</i>		
Sp. Gr.	=	2.611	oxygen		2.610	oxygen	
SiO <sub>2</sub>	=	57.29	30.55		58.41	31.15	
Al <sub>2</sub> O <sub>3</sub>	=	26.52	12.36	} 12.42	25.93	12.08	} 12.19
Fe <sub>2</sub> O <sub>3</sub>	=	0.21	0.03		0.38	0.11	
MgO	=	0.15	0.06	} 4.09	0.18	0.07	} 3.74
CaO	=	7.80	2.23		5.82	1.66	
Na <sub>2</sub> O	=	6.75	1.74		6.45	1.66	
K <sub>2</sub> O	=	0.33	0.06		2.10	0.35	
Ignition	=	1.43			0.93		
		<hr/>			<hr/>		
		100.48			100.20		

The oxygen ratios in the two analyses are as follows:

RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> in *a* = 4.09 : 12.42 : 30.55 = 0.99 : 3 : 7.51  
 in *b* = 3.74 : 12.19 : 31.15 = 0.93 : 3 : 7.67

which is near the atomic ratio of 1 : 1 : 4, agreeing with the formula of andesite = (Na<sub>2</sub>O, CaO) SiO<sub>2</sub> + Al<sub>2</sub>O<sub>3</sub>, 3SiO<sub>2</sub>.

*e.* The soda-oligoclase, which, associated with euphyllite, accompanies corundum at Unionville, Pennsylvania, has been analyzed by Smith and Brush\*.

A specimen in the University collection from the same locality consists of a granular yellowish or brownish-white oligoclase, the small cleavage planes of which are sometimes finely striated. It has patches of a granular gray corundum disseminated through the mass, mixed with minute grains of a hard greenish-black mineral, probably spinel. The corundum in some places altered into a soft crypto-crystalline slightly pearly, white or grayish-white mineral, which appears to be margarite; it is frequently penetrated by the oligoclase and looks as if it was a remnant from its conversion into oligoclase and other species. The analysis of it by Mr. Chatard gave:

SiO <sub>2</sub>	=	59.35	contains oxygen	31.65	
Al <sub>2</sub> O <sub>3</sub>	=	24.16		11.26	} = 11.44
Fe <sub>2</sub> O <sub>3</sub>	=	0.61		0.18	
MgO	=	0.34		0.14	} = 3.52
CaO	=	3.08		0.88	
Na <sub>2</sub> O	=	7.22		1.86	
K <sub>2</sub> O	=	3.78		0.64	
Ignition	=	1.96			
		<hr/>			
		100.50			

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> = 3.52 : 11.44 : 31.65

\* Sil. Journ. [2] XV, 211 and XVI, 44.

which is = 0.92 : 3 : 8.30, or very near 1 : 3 : 9 in accordance with the formula of oligoclase =  $2(K_2O, Na_2O, CaO), 3SiO_2 + 2(Al_2O_3, 3SiO_2)$ .

*f.* The yellowish-white granular feldspar of Mineral Hill, Delaware County, Pennsylvania, above referred to, which contains crystals of corundum altered into fibrolite and other minerals, seems also to be oligoclase.

*g.* The so-called indianite from Chester, Massachusetts, has been proved by C. T. Jackson's\* analysis to be granular oligoclase.

*h.* The white granular feldspar from the locality on the road from Unionville to Kennett Square has been analyzed by Brush and Weld,† who found it to be albite, containing a small percentage of lime. It is frequently the matrix of gray corundum associated with euphyllite (?). The corundum crystals are rough and irregular and are always more or less coated, enveloped or changed into euphyllite, and also a soft, apparently amorphous, mineral, which is probably a variety of margarite, of which, however, I had not enough for an analysis.

The very interesting question presents itself: are the feldspars found in connection with the corundum, the result of the alteration of the latter? I am not prepared to give a positive answer, and believe that it requires a great many more observations before it can be decided. From what I have seen, it appears that there are cases where feldspars have been formed from corundum, and it is very probable that many have thus been formed, but that at the same time a portion of the alumina re-crystallized as corundum, which we then find imbedded in the feldspathic matrix.

Very similar occurrences must have taken place in several other instances, to which I will here refer, viz. ; the crystals of corundum in a matrix of tourmaline and the beautiful, very well defined crystals of it in the chlorite of the Culsagee Mine.

#### 11. TOURMALINE.

Tourmaline has been found in association with corundum at most of the localities already referred to; for example, at Kassoibrod in the Ural, at Naxos in Greece, at Chester, Massachusetts, at Unionville, Pennsylvania, at the Culsagee Mine, rarely at the Cullakenee Mine, and more frequently at Dudleyville, Alabama.

*a.* At Unionville black tourmaline is frequently found in irregular masses of different sizes, from a small grain to several inches in diameter, in the corundum as well as in the minerals resulting from its alteration, especially in the foliated margarite or with zoisite and euphyllite. It sometimes shows crystalline prismatic planes, but is mostly granular and occupies the interstices between the corundum itself.

A far more interesting occurrence is mentioned by Dr. Isaac Lea (loc.

\* C. T. Jackson's, Sill. Journ. [2] XLII, 107.

† Brush and Weld, Sill. Journ. [2] VIII, 390.

cit.) of a crystal of transparent green tourmaline passing through the middle of a prism of diaspore, and the whole enveloped by lamellar crystals of pearly emerylite (damourite, Gth.). Very similar is the occurrence of slender green crystals in the pseudo-fibrous damourite. These tourmalines are in all probability the result of the alteration of corundum, or, the black tourmaline went into solution and re-crystallized in the diaspore and damourite in a similar manner, as apophyllite dissolved in water in a sealed tube under pressure, crystallizes out on cooling, as shown by Wöhler in his well known and important experiment.

*b.* The association of corundum with tourmaline at the Culsagee Mine deserves the greatest attention.

There are masses of black tourmaline, which contain more or less frequently, and irregularly disseminated through them, crystals of white and yellowish-white corundum; plates of chlorite are also, sometimes, penetrating the tourmaline. The corundum crystals have particles of tourmaline intermixed with them, and *vice versa*. On the whole, however, the tourmaline looks more like the *matrix* of the corundum. Sometimes there seems to be an almost imperceptible change of granular corundum into tourmaline. Of the numerous specimens which I have examined, two deserve a fuller description. The first is a small piece of black columnar tourmaline, with a micaceous mineral, probably margarite, and grayish-white corundum. In one case the upper part of the columnar mass of tourmaline is occupied by corundum, which also penetrates into a portion of the tourmaline; the tourmaline frequently contains nuclei of corundum. The second specimen, also from the same mine, for which I am indebted to the kindness of Col. C. W. Jenks, is a pseudomorph of tourmaline after corundum. It is part of a crystal of reddish-gray corundum of a little over two inches in height and about two inches in thickness. It shows three planes of the hexagonal prism and portions of one pyramidal plane. At the upper part of this crystal, almost the entire corundum has been altered into black tourmaline, leaving only a shell of corundum of about one-eighth to one-quarter inch; at its lower part the corundum, although intermixed with tourmaline, is still about one inch in thickness. Plates of green chlorite penetrate both the corundum and the tourmaline.

*c.* At the Cullakenee Mine tourmaline occurs but sparingly. It is associated with foliated pink margarite and another mineral in slender prismatic, longitudinally striated crystals, resembling some varieties of epidote, but in too small quantity for mineralogical determination.

*d.* The occurrence of tourmaline at Bell's Creek, Town's County, Georgia, and Dudleyville, Tallapoosa County, Alabama, presents nothing remarkable.

## 12. FIBROLITE.

For a long time fibrolite has been known to accompany the corundum in the Carnatic, in India, and in the neighborhood of Canton, in China; the variety much used by the Celts in the *stone age* has been obtained

amongst other localities from the vicinity of Chavagnac and Ourouze, in France, where it is associated with *mica*, *cyanite*, *red* and *blue corundum*. One of the most interesting localities is at the Falls of the Yantic, near Norwich,\* Connecticut, where the *small crystals* of sapphire are completely surrounded by fibrolite. This is evidently owing to an alteration of corundum into fibrolite.

At Mineral Hill, Delaware County, Pennsylvania, as I have already mentioned above, corundum, more or less completely altered into fibrolite, occurs in a feldspathic rock. The corundum crystals are generally rough, six-sided prisms, tapering at both ends, from one-half to one and a-half inches in length and from one-eighth to one inch in thickness. They are of various shades between white and brown, often of a rich glove-brown color, many exhibiting a white or colorless star of six rays. This star when magnified shows already a fibrous structure. Where the alteration of corundum has just commenced, a thin coating of a grayish-white color, sometimes not thicker than a varnish, can be observed on the brown corundum. Under a strong glass it is seen to consist of a vitreous mineral, which is fibrous and radiating from the corundum. Many of the crystals have still a core of unaltered corundum, in others every trace of it has disappeared, and fibrolite pseudomorphous after corundum is left, the interior of which is made up of congeries of acicular crystals.

Only with great difficulty I was able to select a sufficient quantity of pure material for analyses.

The following are the results :

Spec. Grav. = 3.286.

	a.	b.	c.	Oxygen.
	Almost Pure.		Purest.	
SiO <sub>2</sub> =	37.76	37.62	37.37	19.93
Al <sub>2</sub> O <sub>3</sub> =	60.27	60.91	60.52†	28.20
Fe <sub>2</sub> O <sub>3</sub> =	0.98	0.94	0.90	0.27
MnO =	0.10	} 0.24	0.10	} 28.47
MgO =	0.18		0.25	
CaO =	0.44	0.40	0.38	
Ignition =	0.73	0.62	0.48	
	100.46	100.73	100.00	

The oxygen ratio of R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> = 1.43 : 1 = 3 : 2, agreeing with the formula Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>.

At several localities in the immediate neighborhood and frequently within the serpentine region, in the State of Delaware, and Delaware County, Pennsylvania, fibrolite is found, which partly at least seems to have been derived from the alteration of corundum. I wish to call par-

\* C. U. Shepard, Sil. Journ. [3] IV, 180.

† By difference.

ticular attention to that which occurs between Media, Delaware County, Pennsylvania, and the Asylum for Feeble-Minded Persons. On a fresh fracture, the silky lustre of its fibres can be easily perceived, but it has a slaty structure and is associated with white and pale blueish crystals of cyanite and brown staurolite crystals, many of them in twins. The whole reminds one immediately of the well known staurolite and cyanite crystals in the paragonite slate of St. Gothard.

A similar fibrolite slate is found near the Culsagee Mine, Macon County, North Carolina.

Amongst fifty crystals of corundum from Laurens District, South Carolina, part of which are converted into damourite, I found one broken crystal, the outside of which is changed into fibrolite. It is an irregular six-sided prism,  $\frac{5}{8}$  of an inch long, not quite half an inch thick, with a core of unaltered brownish corundum  $\frac{1}{4}$  of an inch in diameter. The fibrolite is radiating from the surface towards the core, and the surface is covered with crystalline aggregates of fibrous fibrolite and a few small plates of damourite.

For a highly interesting specimen, I am indebted to John C. Trautwine, Esq. He found it many years ago at Germantown, Pennsylvania. It consists of granular quartz with streaks of grayish-white fibrous fibrolite through it from  $\frac{1}{4}$  to  $\frac{3}{8}$  of an inch in width, but less than a line in thickness. The centre of several of these streaks is occupied by blue bladed cyanite. It is impossible to decide, whether this is a case of paramorphism, in which the monoclinic changes into the triclinic silicate of alumina,  $Al_2O_3$ ,  $SiO_2$ , or whether both crystallized from the same medium in their present form.

### 13. CYANITE.

Cyanite is a very usual associate of corundum. It is found with it on the St. Gothard, near Petschau in Bohemia, and in several other foreign localities. It is one of the most important results of its alteration. I have dwelled at fuller length upon the change of corundum into fibrolite, because there we have *real pseudomorphs* which appear not to exist with, chemically, the same aluminous silicate, the bladed structure of the cyanite immediately obliterating, probably, every trace of the original form. However, I shall describe a number of specimens of cyanite, containing still a nucleus of the original mineral, from which they resulted.

a. At Litchfield and Washington, Connecticut, rolled masses of cyanite have been found, which contained corundum and diaspore. I am indebted to Prof. Geo. J. Brush, for a very beautiful and instructive specimen from Newton, Connecticut. It consists of irregularly arranged bladed masses of gray and blueish-white and blue color. In some places, and especially, where the blades meet, a white or yellowish-white micaceous mineral is intermixed; imbedded in it sometimes is diaspore, and in one place in immediate contact with the cyanite, is a rounded fragment of a slightly pink colored corundum.



*b.* Another superb specimen was presented to me by Col. Jos. Willcox, who collected it a short time ago at Swannanoa Gap, Buncombe County, North Carolina. It consists of a fragment of an irregular hexagonal prism of corundum of about two inches in length and one inch in thickness, of a deep blue and white color, and showing the perfect rhombohedral cleavage; it is surrounded by pale blueish-white cyanite and damourite. The surface of the corundum appears much eaten and the specimen is a beautiful illustration of the alteration of corundum into the two other minerals.

*c.* A third specimen I received about two years ago from Mr. Hanna, Assistant Assayer of the Mint in Charlotte, North Carolina. It comes from Wilkes County, North Carolina. At that time I had no idea of the importance, in a scientific point of view, of some insignificant particles of corundum in cyanite, and procured the specimens only on account of the beauty of the latter. Mr. Hanna had another piece, which, if my memory serves me right, contains a mass of corundum of about one inch in diameter. The cyanite has an impure blueish-greenish color and coarsely bladed columnar crystals and crystalline masses, some of the blades 1 to  $1\frac{1}{2}$  inches across. Several small fragments and grains of corundum, of a gray to a reddish-brown color are visible in the mass of cyanite, one of them showing the usual striation very distinctly. A minute quantity of damourite is also present.

I shall now enter into the discussion of some points with reference to the occurrence of corundum in Gaston and Rutherford Counties, North Carolina, which form a close connection with the remarks just made, although I may be compelled to anticipate some facts, which should not yet be discussed.

At Crowder's Mountain, and Clubb's Mountain, in Gaston County, and at a recently discovered locality in Rutherford County, North Carolina, corundum is found massive and in crystalline pieces, sometimes showing a hexagonal form; its color is from deep blue to purple, and grayish-blue intermixed with white. The unaltered corundum is somewhat ferruginous and invariably contains crystals of rutile of different sizes disseminated through the whole mass. This corundum, however, is sometimes altered into a compact margarite, which coats the blue crystals, but generally into damourite and cyanite, which are associated with gold, granular quartz, etc. This alteration, however, goes frequently farther and leaves not a trace of corundum, and often nothing but scoriaeous masses, the cavities frequently still containing small crystals of cyanite coated with a brownish-black limonite, and rutile in brilliant crystals or coated in the same manner. But there are two new products of the alteration associated with these, pyrophyllite and lazulite. The same association of cyanite, rutile, pyrophyllite and lazulite in an arenaceous sandrock is found at Graves Mountain, Lincoln County, Georgia, and although as far as I am aware, corundum has never been found at this place, there can be very little doubt that at this locality also all these



species except rutile and quartz owe their existence to the former presence and subsequent alterations of corundum.

The same is in all probability true with reference to the occurrences of pyrophyllite, both radiated, stellate, and the slaty in Montgomery, Randolph, Moore, Chatham, and Orange Counties of North Carolina, and perhaps Chesterfield District, South Carolina.

#### 14. STAUROLITE.

With the damourite, resulting from the alteration of corundum at the Culsagee Mine, are found very few and minute brown grains of subvitreous lustre; the grains are massive and of irregular shape and do not show a trace of a crystalline form. Their spec. grav. was found to be = 3.711, and the analysis showed them to be staurolite. It gave :

SiO <sub>2</sub>	=	27.91	contains oxygen	--	14.49	
Al <sub>2</sub> O <sub>3</sub>	=	52.92	" "		24.74	} 26.80
Fe <sub>2</sub> O <sub>3</sub>	=	6.87	" "		2.06	
FeO	=	7.80	" "		1.73	} 3.04
MgO	=	3.28	" "		1.31	
CaO and MnO	=	traces				
Ignition	=	1.59				
		<hr/>				
		100.37				

The oxygen ratio 3.04 : 26.80 : 14.49 is = 1 : 8.8 : 4.8 or near 1 : 9 : 5 giving the formula 2RO, SiO<sub>2</sub> + 2 (3Al<sub>2</sub>O<sub>3</sub>, 2SiO<sub>2</sub>).

#### 15. PYROPHYLLITE.

In his "Chemical and mineralogical relations of the metamorphic rocks," T. S. Hunt\* says: "*The last term in this exhaustive process appears to be represented by the disthene (cyanite) and pyrophyllite rocks, which occur in some regions of crystalline rocks.*"

I suggested under the heading "*cyanite*" that the pyrophyllite found in several of the Counties of North Carolina, South Carolina and Georgia, is the result of the alteration of the former, perhaps, from Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> into Al<sub>2</sub>O<sub>3</sub>, 3 SiO<sub>2</sub> + H<sub>2</sub>O.

This view is sustained by pseudomorphs of pyrophyllite in the form of cyanite from Villa Rica, in Brazil, described by F. Sandberger.†

An association very similar to that at Crowder's Mountain, North Carolina and elsewhere, viz. : cyanite, pyrophyllite, damourite, hematite, and lazulite, occurs at Horrsjöberg, in the District of Elfsdalen, in rutile Wernmland and Westana in Sweden. That these were formed under similar circumstances cannot be doubted.

Several other hydrous aluminous minerals have been found in association with corundum or with minerals which are the product of its alteration; for example, those accompanying the beauxite in the southern

\* T. S. Hunt, Sill, Journ. [2] XXXVI, 222.

† F. Sandberger, Leonhard-Broon's Jahrbuch der Mineralogie, 1855, 315.

part of France, the dillnite with the diaspore of Schemnitz, and others, of which the species has not been sufficiently identified; they are mostly amorphous and their relation to the corundum is not striking enough to dwell more fully upon them. I turn my attention now to

#### 16. DAMOURITE.

This species has been established on a mica-like mineral, an aggregate of fine scales, forming the gangue of cyanite at Pontivy, Brittany. It will be seen in the sequel that it is one of the most important products of alteration of corundum, from which it is either *directly* formed, or *indirectly*, after the corundum has first been changed into cyanite or fibrolite, which latter are subsequently converted into damourite. There is hardly a species, which assumes so many different shapes as this, and it is often impossible to determine it without analysis. S. P. Sharpless\* was the first to prove that mica-like crystals, which accompany the diaspore from near Unionville, Newlin Township, Chester County, Pennsylvania, which always had been mistaken for margarite (emerylite) were damourite.

At Unionville, damourite is found in the following forms :

*a.* In crystals frequently having the lateral and sometimes the basal planes well developed; they appear to be hexagonal plates, but are probably rhombic. They are sometimes radiating and fan-shaped, and the crystalline plates from one to three inches in diameter. Their color is generally white to greenish-yellowish and brownish-white, but when treated with chlorhydric acid, which removes a little ferric hydrate which colors them, they are white with a very delicate shade of sea green—rarely as deep as grass-green. Their lustre is pearly, sometimes inclining to vitreous.

These crystals or crystalline plates of larger or smaller size are directly attached to the granular grayish or brownish-white corundum or in the mass of the same; occasionally there is between them and the corundum a small seam of a crystallized dark-green chloritic mineral. Black tourmaline is another not uncommon associate, and especially, where the rare mineral diaspore appears, slender crystals of dark blueish, or brownish, green tourmaline are met with. This is the variety analyzed by S. P. Sharpless and Dr. G. A. Koenig (*a*).

*b.* Another variety of damourite consists of an aggregation of grayish and yellowish-white scales of one-sixteenth to not over one-quarter inches in diameter. After cleaning them with dilute chlorhydric acid they are silver-gray. They form a coating upon and sometimes occupy the whole of former corundum crystals and their aggregations are real pseudomorphs after corundum, generally with a core of original mineral. Dr. Isaac Lea has a fragment of a beautiful crystal of blue corundum over three inches in length and about two and a-half inches in diameter, which is coated with a coat of scaly damourite from one-eighth to one

\* S. P. Sharpless, *Sill. Journ.* [2] XLVII, 319.

fourth inch in thickness. He very kindly furnished me with some for analysis (see below *b1*). He has presented me with a fine crystal of gray corundum, about two-thirds of which is changed into damourite. Col. Jos. Willcox, in his rich collection of American corundums, has several good crystals, of which he very generously contributed the material for analysis (see below, *b2*).

*c.* Another very beautiful variety of the same mineral forms also pseudomorphous crystals after corundum. The material for analysis was from a fragment of a crystal, showing on two sides the remnant of a pyramid. It contains a nucleus of gray corundum from which a very fine scaly white pearly damourite is radiating, giving it a pseudo-fibrous structure (*c*).

*d.* The scales of damourite occasionally become so fine that they cannot be distinguished with the naked eye and the mineral becomes massive, sometimes globular, sometimes with a slaty structure, similar to talc slate. This is often mixed with aggregation of larger scales of a greenish-white color and pearly lustre. Dr. Koenig has made an analysis of the massive globular greenish-white crypto-crystalline variety (see below, *d*).

*e.* A white or grayish-white variety of a fine scaly, often crypto-crystalline, structure, sometimes slaty, generally pseudo-fibrous, the apparent fibres from one-half to over six inches in length, frequently invests the granular grayish-white corundum. The lustre is generally very feeble, otherwise pearly, inclining to silky. Scales of damourite of a white or greenish color are disseminated through the white fibrous mass, sometimes in small veins or accumulating into masses to a scaly granular rock. An analysis of the pseudo-fibrous white damourite by Dr. Koenig is given below (*e*).

On one side and as a rule furthest from the corundum, it gradually becomes dull-green and changes into pure granular chlorite.

*f.* Next to the corundum is generally another variety of damourite, forming a seam between it and the white (*e*); it is from one-fourth to two inches in thickness.

Whilst crypto-crystalline and consisting of exceedingly minute scales, they are arranged in fibres at right angles to the corundum. This variety of damourite much resembles some kinds of serpentine. It has a yellowish oil-green color, its lustre is waxy or dull. It is remarkable that the slender crystals of tourmaline, which are frequent in the white variety (*e*) and which penetrate into the chlorite, have not been observed in any of the numerous specimens which I had for examination.

I shall give below my analysis of a sample, investing a mass of gray corundum (*f1*), and the mean of two analyses by Mr. Th. M. Chatard (*f2*), of a sample taken between the corundum and the white variety (*e*).

*g.* The highly interesting pseudomorphs of damourite after corundum from Laurens District, South Carolina, probably occur in mica slate. I have already stated that most of the crystals of corundum from this locality are coated with a micaceous mineral, which the analysis proved

to be damourite. The pseudo morphous crystals show the shape of the corundum but are flattened as if by exposure to a heavy pressure. Many still contain a nucleus of unaltered corundum, others are entirely changed. They are aggregates of small yellowish-white scales. The material, which I have analyzed, was first purified by dilute chlorhydric acid and then presented the appearance of silver-white scales (*g*).

*h*. Very similar is the damourite which forms a bed of *mica schist* at the Culsagee Mine. The scales are somewhat larger than those from South Carolina, and the corundum crystals which still exist in it, not quite as deeply altered. They are associated with small grains of massive staurolite and some other black minerals, probably menaccanite, etc. An analysis of the scales purified by chlorhydric acid was made by Dr. Koenig, the results of which is given below (*h*).

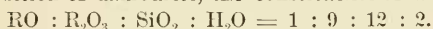
*i*. The damourite, investing the crystals and masses of blue corundum at Crowder's Mountain and resulting from its alteration, occurs in scales, which are generally coated with ferric hydrate. A sample purified by chlorhydric acid was analyzed by Mr. Thos. M. Chatard (see below, *i*).

The results of the analyses of the various varieties of damourite, are as follows :

Spec. Gr.	=	<i>a.</i>	<i>b1.</i>	<i>b2.</i>	<i>c.</i>	<i>d.</i>	<i>e.</i>
SiO <sub>2</sub>	=	2.851	—	2.843	—	2.857	2.892
Al <sub>2</sub> O <sub>3</sub>		43.03	45.49	45.57	45.86	45.73	45.73
Fe <sub>2</sub> O <sub>3</sub>		39.06		34.83	37.65	37.10	36.30
MgO		1.48	2.34	2.94	0.59	1.30	0.83
CaO		0.30	—	0.83	0.55	0.34	0.54
Li <sub>2</sub> O		trace.	—	0.40	0.31	trace.	0.74
Na <sub>2</sub> O		trace.	—	trace.	trace.	trace.	trace.
K <sub>2</sub> O		0.58	0.32	0.87	0.80	0.88	0.58
Ignition		10.05	9.88	10.16	10.40	10.50	10.49
		5.40	3.89	5.30	4.74	4.48	5.17
		99.90		100.90	100.90	100.33	100.38
Spec. Gr.	=	<i>f1.</i>	<i>f2.</i>	<i>g.</i>	<i>h.</i>	<i>i.</i>	
SiO <sub>2</sub>		2.779	2.760	—	2.867	2.860	
Al <sub>2</sub> O <sub>3</sub>		46.98	46.60	45.71	45.62	43.51*	
Fe <sub>2</sub> O <sub>3</sub>		35.13	32.39	34.12	35.93	37.85	
MgO		0.61	2.54	3.45	2.93		
CaO		1.32	2.01	0.71	0.34	0.31	
Li <sub>2</sub> O		0.13	trace.	0.48	trace.	0.42	
Na <sub>2</sub> O		trace.	trace.	trace.	trace.	trace.	
K <sub>2</sub> O		0.76	0.54	0.49	0.71	1.04	
Ignition		10.74	10.39	10.36	9.40	11.35	
		4.77	4.81	4.67	4.93	7.73*	
		100.44	99.28	99.99	99.86	102.21	

\* Mean of three determinations.

Although the object of many of these analyses was only to determine the species, the material for investigation was selected with great care. Some of them, notwithstanding, contained minute quantities of corundum, by which the per centage of the silica or alumina is slightly increased; the majority, however, fully agree with the established composition of damourite, the constituents of which have the oxygen ratio :



Only the damourite from Crowder's Mountain would give for water the ratio : 3. This is the result of three determinations, all agreeing with each other. Some of the damourite varieties have a portion of the alumina replaced by the ferric oxide.

#### 17. EPHESITE. LESLEYITE.

In his investigations on *emery*, J. L. Smith (*l. c.*) describes under the name "*ephesite*," a mineral which he states to have a lamellar structure and to resemble white cyanite. I will give below the analysis of ephesite, by Dr. Smith, and also one, which I made from material kindly furnished me by him for my investigations on corundum. It will be seen that they compare pretty well. I must add, however, that Dr. Smith's analysis should be considered the better, because he had a larger quantity and probably cleaner material for his examination. The main object of *my* analysis was to see whether ephesite contains a *mechanical admixture of corundum*, which was most conclusively proven.

Not having had an opportunity to see ephesite, Dr. Isaac Lea called (*l. c.*) a similar mineral from Unionville, *lesleyite*. He recognized the change of the hard corundum into soft minerals and in the absence of analyses, he considered all those which were fibrous and compact as identical. This is undoubtedly a very excusable error, because it is next to impossible to distinguish these minerals without chemical tests, and credit should be given to him for having brought to light these interesting varieties.

Of the fibrous and compact damourites I have already spoken, the margarite belonging here, I shall consider afterwards; I now will dwell only upon such varieties, as have been generally recognized as *true lesleyites*. Some of these have been the subject of investigations by S. P. Sharpless,\* and Dr. J. L. Smith,† and of observations by G. J. Brush.‡ There are three principal varieties of lesleyite.

*a.* The first is fibrous and divergent. It is slightly grayish-white, the surface is discolored by ferric hydrate, but interior of the mass appears to be free from it. Its lustre is pearly inclining to silky, it is scratched by fluorite, but scratches quartz easily, and is associated with scaly damourite.

*b.* The second variety resembles the first very much, but is more ferru-

\*S. P. Sharpless, *Sill. Journ.* [2] XLVII, 319.

†J. L. Smith, *Sill. Journ.* [2] XLVIII, 254.

‡G. J. Brush, *Appendix to 5th edit. of Dana's Mineralogy*, New York, 1872.

ginous and less pure; it is associated with damourite and pattenonite. It has small cavities through the whole mass. Its color is reddish.

c. The third variety has frequently a chloritic mineral intermixed with it. The lesleyite itself is fine fibrous columnar, sometimes divergent; its color is between grayish-greenish and brownish-white, and its lustre between silky and vitreous. It is easily scratched by the knife, but is harder than apatite. Some parts of it scratch quartz.

Mr. Thos. M. Chatard and I analyzed the white variety *a*; and Dr. Koenig and I the varieties *b* and *c*; to which, for comparison, are added the analyses of S. P. Sharpless and J. L. Smith.

*Ephesite:*

	J. L. Smith.	Genth.
SiO <sub>2</sub> =	30.70	31.34
Al <sub>2</sub> O <sub>3</sub>	55.67	55.55
Fe <sub>2</sub> O <sub>3</sub>	—	1.04
MgO (trace MnO)	—	trace.
CaO	2.55	3.82
Li <sub>2</sub> O	—	trace.
Na <sub>2</sub> O	5.52	3.27
K <sub>2</sub> O	1.10	1.68
Ignition	4.91	5.12
	100.45	101.72

The fusion with calcic carbonate with ammonic chloride gave me 10.26 per cent. of corundum.

The oxygen ratios for RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O are :

Smith =	2.34	: 25.94	: 16.37	: 4.35	= 1	: 11.1	: 7	: 1.9
Genth =	2.22	: 26.20	: 16.72	: 4.55	= 1	: 11.8	: 7.5	: 2.0.

I have endeavored to calculate from these data the probable composition of this mixture, but failed. If we had any means to determine the actual amount of free corundum, which I suppose will be between 15 and 20 per cent., we would probably have better success.

*Lesleyite:*

Sp. Gr. =	<i>a. White.</i>			<i>b. Reddish.</i>		
	Genth.	Chatard.	Sharpless.	Genth.	Koenig.	C.W. Roepper
		3.200	3.203		3.059	2.870
SiO <sub>2</sub> =	32.32	32.32	33.59	21.96	31.90	47.00
Al <sub>2</sub> O <sub>3</sub>	56.43	55.23	55.41	} 56.85	54.09	33.27
Fe <sub>2</sub> O <sub>3</sub>	0.29	—	—		0.51	2.84
MgO	0.38	} 0.73	—	0.13	0.34	—
CaO	0.32		—	0.13	—	—
Li <sub>2</sub> O	faint traces.		—	faint traces.		—
Na <sub>2</sub> O	0.32	0.64	—	0.35	1.01	—
K <sub>2</sub> O	7.31	7.82	7.43	7.83	8.71	9.97
Ignition	4.01	3.86	4.30	4.09	4.20	6.71
	101.38	100.60	100.73	101.34	100.76	99.79



In the analysis of *a*, I found by the fusion with calcic carbonate and ammonic chloride 21.40 per cent., and in *b*, 17.78 per cent. of *free corundum*.

The analysis of the reddish variety by C. W. Roepper contains evidently about 15 per cent. of *corundum in the silicic acid* which he found.

S. P. Sharpless suggested that both varieties are *the products of the action of water containing alkaline silicates upon corundum, and are more nearly related to pinite than to any other mineral species*; Prof. Brush, that both ephesite and lesleyite are *mixtures of corundum, and probably diaspoire, with a mica, similar to the damourite found at the lesleyite locality; and that the foliated soft material is damourite or a hydrous mica near that species*.

In my investigations I had already ascertained that lesleyite contains a large per centage of free corundum, when I received the *Appendix to Dana's Mineralogy by Prof. Brush*, and I am happy to be able to prove that, at least, the greater part of his suggestions are correct.

I do not believe that there is any admixture of diaspoire, but calculating from the amount of potash found in the white lesleyite the per centages requisite for a damourite, most similar in appearance to it (see analysis of damourite *e* by Dr. Koenig), we get :

SiO <sub>2</sub>	=	31.87	}	=	68.48	Damourite.
Al <sub>2</sub> O <sub>3</sub>	=	25.30				
Na <sub>2</sub> O	=	0.40				
K <sub>2</sub> O	=	7.31				
H <sub>2</sub> O	=	3.60				
					30.00	Corundum.
					1.52	Silicates, etc.

The analysis of Sharpless gives about 69 per cent. of damourite and nearly the same amount of corundum as my own.

The calculation of the analysis of the reddish variety gives less satisfactory results, owing to the greater impurity of the mineral; but it corresponds with about 70 per cent. of damourite, 27 per cent. of corundum and 3 per cent. of other admixtures.

*c.* The third variety of lesleyite is of an entirely different nature. The analysis gave :

	=	Genth.	Koenig.
Sp. Gr.	=	—	3.157
SiO <sub>2</sub>	=	35.68	34.80
Al <sub>2</sub> O <sub>3</sub>		60.29	59.77
Fe <sub>2</sub> O <sub>3</sub>		0.72	0.73
MgO		0.29	—
Li <sub>2</sub> O		faintest trace.	—
Na <sub>2</sub> O		0.41	not det'd.
K <sub>2</sub> O		0.96	not det'd.
Ignition		1.78	2.05
Corundum		—	2.20
		100.13	99.55

By the fusion with calcic carbonate and ammonic chloride I obtained 11.08 per cent. of corundum; the 2.20 per cent of corundum in Dr. Koenig's analysis remained unacted upon by the fusion with sodic carbonate.

The oxygen ratios in these analysis is for  $RO : R_2O_3 : SiO_2 : H_2O$ , as follows :

Genth = 0.39 : 28.32 : 19.03 : 1.58 = 1 : 72.6 : 48.8 : 4  
 Koenig = (0.39) ass'd : 28.07 : 18.56 : 2.05 = 1 : 72.0 : 47.6 : 5.3.

It will be seen that the ratio of  $R_2O_3 : SiO_2$  is exactly = 3 : 2, which is that of fibrolite. Although it is very probable that this variety, like the two others is *originally an alteration of corundum into fibrolite*, the latter is almost completely changed in the first two varieties and to a great extent already in the third. I did not succeed in calculating from the small quantities of potash, soda and magnesia any of the admixtures. The 11.08 per cent. of corundum which I found, indicate the presence of probably about 15 or 16 per cent. of this substance.

#### 18. PARAGONITE.

A highly interesting occurrence of corundum is that at "Oehsenkopf," near Schwarzenberg, in Saxony. It is found in granular masses or isolated grains of a blueish-gray color in a slaty rock of a brownish ash-gray color. Associated with the corundum are small scales of dark green chloritoid and a minute quantity of a foliated white brilliant mineral, which is probably diaspore. The slaty matrix consists of very fine white and brownish-white scales, and the whole appearance is so very similar to that of some varieties of damourite resulting from the alteration of corundum, that I considered a chemical analysis as very desirable. The material for it was selected with great care and was found to have the following composition :

$SiO_2$	=	43.70
$TiO_2$	=	3.50
$Al_2O_3$		39.60
$Fe_2O_3$		0.66
MgO		trace.
CaO		0.56
$Li_2O$		trace.
$Na_2O$		6.52
$K_2O$		0.93
Ignition		4.83
		<hr/>
		100.30

The presence of titanitic acid was surprising, as no rutile could be detected with a very good magnifying glass in any of the particles. Some of the slate was therefore carefully crushed without grinding and the lighter particles were washed off. The heavier residue, when examined under the microscope, showed numerous grains of yellowish-brown rutile.

Deducting this from the analysis, the composition of this slate is that of paragonite, the analyses of a variety of which, from St. Gothard by Rammelsberg, and of another from Pregatten, in Tyrol (Pregattite) by Oellacher, I will give for comparison :

	St. Gothard.	Pregatten.	Ochsenkopf.			
SiO <sub>2</sub>	= 46.81	44.65	45.14	contains oxygen	24.07	
Al <sub>2</sub> O <sub>3</sub>	40.06	40.41	40.91	"	"	19.06
Cr <sub>2</sub> O <sub>3</sub>	—	0.10	—			} 19.26
Fe <sub>2</sub> O <sub>3</sub>	trace. FeO=0.84	Fe <sub>2</sub> O <sub>3</sub> =0.68	"	"	0.20	
MgO	0.65	0.37	trace.			
CaO	1.26	0.52	0.58	"	"	0.17
Na <sub>2</sub> O	6.40	7.06	6.74	"	"	1.74
K <sub>2</sub> O	trace.	1.71	0.96	"	"	0.16
Ignition=	4.82	5.04	4.99	"	"	4.44
	<hr/> 100.00	<hr/> 100.70	<hr/> 100.00			} 2.07

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O is equal to 1 : 9.3 : 11.6 : 2.1 or very near to 1 : 9 : 12 : 2, which is that of damourite.

Paragonite is essentially a *soda damourite*.

The mineral from the Ochsenkopf analyzed by John does not belong to this species.†

I have above alluded to a peculiar rock, a slaty fibrolite with staurolite and cyanite, found in the neighborhood of Media, Delaware County, Pennsylvania, and also near the Culsagee Mine, in Macon County, North Carolina, and stated that the whole appearance of these slates was that of the paragonite slates of St. Gothard. After having already proved the alteration of corundum and fibrolite into damourite, and that of the Ochsenkopf corundum into paragonite, the question suggests itself—*may not the whole of the paragonite slates of St. Gothard and elsewhere be the result of the alteration of corundum or fibrolite?*

#### 19. EUPHYLLITE.

Euphyllite accompanied by tourmaline and zoisite is a very rare associate of corundum at Unionville. It is undoubtedly like the others, resulting from its alteration. As I had not a sufficient quantity of pure material, no new analysis has been made, and really there was no necessity for it, because the analyses of Smith and Brush leave no doubt about its composition.

The micaceous mineral, which is found with the corundum and albite near Unionville, and which resembles muscovite, gave Dr. Koenig in two partial analyses about 42 per cent. of silicic acid.

This is undoubtedly the same as that analyzed by Sharpless\* and those of a similar per centage of silicic acid from Asia Minor and Nicaria, analyzed by J. L. Smith.

#### 20. JEFFERISITE.

Jeffersite, a species first distinguished by Prof. Brush, is frequently the result of the alteration of chlorite, hence indirectly of corundum. At

† Dana's Mineralogy, 5 edit., 482.

\* Dana's Mineralogy, 5 edit., 489.

the Unionville locality it is rarely met with, but sometimes it is found in irregular and imperfect hexagonal plates and crystals of a brownish-yellow color. It exfoliates like that from West Chester.

At the Culsagee Mine it is of more frequent occurrence, and the chlorite shows very often an incipient alteration by a discoloration of the laminae, which turns brown or brownish-yellow. It is generally found, when completely altered, in plated masses of a yellowish-brown color, which cannot be distinguished by their physical characters and their manner of exfoliation, from that of the original locality. There is another variety at the Culsagee Mine, which is associated with a considerable quantity of corundum. It occurs in fine greenish-brownish-yellow scales, not over one-eighth of an inch in diameter. It exfoliates, but not as remarkably as either of the other varieties.

The following were analyzed :

*a.* The broadly foliated, from the Culsagee Mine by Dr. Koenig (*a* 1) and Mr. Thos. M. Chatard (*a* 2).

*b.* The greenish-brownish-yellow fine scaly, by Mr. Thos. M. Chatard (*b.*)

*c.* and for comparison the broadly foliated from West Chester, by Dr. Koenig (*c* 1) and Mr. Thos. M. Chatard (*c* 2), to which is added (*c* 3) the analysis by Prof. Brush.

	Culsagee.			West Chester.		
	<i>a</i> 1.	<i>a</i> 2.	<i>b.</i>	<i>c</i> 1.	<i>c</i> 2.	<i>c</i> 3.
SiO <sub>2</sub>	33.93	33.77	34.00	33.35	34.40	37.10
Al <sub>2</sub> O <sub>3</sub>	17.38	17.56	20.36	17.78	16.63	17.57
Fe <sub>2</sub> O <sub>3</sub>	5.42	5.61	4.91	7.32	8.00	10.54
FeO	0.50	0.50*	0.42	2.11	2.11*	1.26
NiO	0.35	not det'd.	0.57	—	—	—
MgO	23.43	22.48	21.71	19.26	19.30	19.65
CaO	—	—	—	—	—	0.56
Na <sub>2</sub> O	—	—	—	not det'd	not det'd	trace.
K <sub>2</sub> O	—	—	—	—	—	0.43
Ignition	19.17	20.30	18.50	19.87	19.03	13.76
	100.18	100.22	100.47	99.69	99.47	100.87

The oxygen ratios for RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O are as follows :

<i>a</i> 1	=	2.94	:	3	:	5.59	:	5.26
<i>a</i> 2	=	2.77	:	3	:	5.48	:	5.49
<i>b</i>	=	2.43	:	3	:	5.00	:	4.50
<i>c</i> 1	=	2.33	:	3	:	5.09	:	5.05
<i>c</i> 2	=	2.42	:	3	:	5.42	:	5.00
<i>c</i> 3	=	2.21	:	3	:	5.23	:	3.23

The discrepancies in these analyses hardly admit of constructing a formula. The analyses *a*1 and 2 give nearly 6RO + 2R<sub>2</sub>O<sub>3</sub> + 5SiO<sub>2</sub> + 10H<sub>2</sub>O, and *b*, *c*1 and 2 nearly 5RO + 2R<sub>2</sub>O<sub>3</sub> + 5SiO<sub>2</sub> + 10 H<sub>2</sub>O.

The greatest, and to me unexplainable difference, exists in the results of Prof. Brush and Dr. Koenig and Mr. Chatard in the amount of silicic acid and water in the West Chester Jeffersonite. Dr. Koenig made his analysis with finely powdered material, which has been exposed to the dry air of the room; Mr. Chatard took his material from another specimen, and after powdering, dried it for *four days over sulphuric acid in a vacuum*; in the same manner the Culsagee mineral was treated.

\*Mr. Chatard determined only the ferric oxide, and took for the ferrous oxide Dr. Koenig's result.

## 21. CHLORITE.

I have mentioned in the geological outline, that chlorite rocks have been observed in almost every locality where corundum occurs in large masses or beds. It remains to examine into a number of peculiar associations between chlorite and corundum, in order to point out their relation to that of the entire chloritic beds.

*a.* Near Unionville, in the shaft alongside of the road to Kennett Square, chlorite occurs very conspicuously; it is intimately mixed with spinel, containing a considerable admixture of corundum (see above). The results of the explorations there, were not sufficiently encouraging, and the mining operations have therefore been abandoned. They have furnished, however, a few interesting scientific facts, as I have shown.

*b.* At the principal Unionville locality, chlorite is found under various circumstances. It sometimes forms a lining of minute dark green crystals, between the corundum and the foliated damourite; then, it is disseminated through the corundum in small scales or seams; and again it is met with, adjoining the large corundum bed, in boulder-like masses of fine scales, showing a lamination around a centre, which frequently, in breaking them open, consists of a nucleus of granular corundum. This chlorite is of a dull olive-green color, but often under the influence of the atmosphere, converted into reddish or yellowish-brown scales or even a ferruginous clay.

In a specimen in the University collection of nearly one foot in diameter, there seems to have been a fracture in the granular corundum, which allowed the liquid, producing the alteration, to percolate to the centre of the mass, and to deposit in the heart of the specimen, a small quantity of green chlorite, surrounded by a concentric layer of white granular corundum, upon which is a layer of scaly chlorite, slightly ferruginous and yellowish in immediate contact with the corundum, graduating into green. The whole nucleus, of about two inches in diameter is enveloped in a mass of yellowish-gray and brownish decomposed chlorite, of which I shall give two analyses by Dr. Koenig. (*b*, 1 and 2).

*c.* Another variety of chlorite from Unionville, originates from the alteration of damourite and tourmaline, which two minerals result from that of corundum. The white pseudo-fibrous variety of damourite (*c*), gradually assumes a slightly greenish tint from an admixture of fine scales of chlorite, which rapidly increases and soon form a massive variety of a light olive-green finely granular chlorite. The slender tourmaline crystals, which start in the white damourite, pass on into the chlorite, but for a short distance only; they are soon entirely altered into fine scaly chlorite, and these pseudomorphs of chlorite after tourmaline, are imbedded in the granular matrix like the original tourmaline. This is a highly interesting occurrence, and quite similar to that described by G. Rose (l. c.), as occurring in the chlorite slates associated with corundum, at Kassoibrod in the Ural.

Mr. Thos. M. Chatard has furnished me with two analyses, (*c*, 1 and 2)

of this fine scaly granular chlorite, and another one, which I shall copy for comparison (*c.* 3) has lately been published by A. R. Leeds, in his contributions to mineralogy.\*

*d.* The Culsagee Mine, near Franklin, North Carolina, has furnished a great variety of specimens of extraordinary interest.

There are some, which are aggregations of dark green foliated chlorite, having distinctly visible the rough outlines of hexagonal crystals of corundum, and in their centre the unaltered mineral; others again are more irregular in shape, and appear to have been fragments of massive corundum before they were converted. The nuclei of unaltered corundum, are often free from any admixtures, often, however, containing through their mass laminae of chlorite, at times in large quantities.

But there are frequently specimens met with containing *perfect and brilliant crystals* of corundum, which appear to have formed *after* a great portion of the original corundum had changed into chlorite, as if there had been an excess of alumina ready for combination, which, not finding a supply of the requisite amount of silicic acid and bases, had again crystallized as corundum.

The chlorite in immediate contact with the unaltered minerals, whether corundum or spinel, has often a fine scaly pseudo-fibrous structure, which at a greater distance assumes the more laminated shape; however, a great portion is laminated, where it touches either spinel or corundum, and in reality some of the largest plates, three or four inches in diameter, contain a considerable quantity of corundum disseminated through their mass.

The following varieties from the Culsagee Mine were analyzed; broadly foliated dark-green (*d1*) by myself, (*d2* and 3) by Mr. Thos. M. Chatard, and a fine scaly variety diverging from corundum, (*d4* and 5), by myself.

*e.* Similar nuclei of unaltered corundum in foliated chlorite have been observed amongst the specimens from Shooting Creek, Clay County, North Carolina.

The decomposed chlorites from Unionville gave:

		<i>b1</i> Brownish-red.	<i>b2</i> Yellowish-gray.
SiO <sub>2</sub>	=	31.35	32.80
Al <sub>2</sub> O <sub>3</sub>	=	21.58	26.07
Fe <sub>2</sub> O <sub>3</sub>	=	14.17	9.80
MgO	=	16.67	17.70
Ignition	=	14.45	13.75
		98.22	100.12

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O is very near = 1.5 : 3 : 3.5 : 2.5, which can be expressed by the formula : 2(3 RO, 2 SiO<sub>2</sub>)

\*A. R. Leeds, Sill. Journ. [3] VI, 25.



+ (4R<sub>2</sub>O<sub>3</sub>, 3 SiO<sub>2</sub>) + 10 H<sub>2</sub>O, representing the product of the decomposition of chlorite.

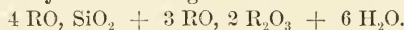
	c1.	c2.	c3.		
SiO <sub>2</sub>	==	29.43	29.59	30.62	
Al <sub>2</sub> O <sub>3</sub>		22.08	22.18	21.73	
Fe <sub>2</sub> O <sub>3</sub>		1.41	1.33	0.42	
FeO		5.64	5.77	5.01	
MgO		28.46	28.54	29.69	
Li <sub>2</sub> O		not det'd.	not det'd.	0.11	
Na <sub>2</sub> O		"	"	0.14	
Ignition		12.40	12.40	12.26	
		<hr/>	<hr/>	<hr/>	
		99.42	99.81	99.98	
		<hr/>	<hr/>	<hr/>	
		d1.	d2.	d3.	d4.
SiO <sub>2</sub>	==	27.56	27.28	27.17	29.48
Al <sub>2</sub> O <sub>3</sub>	==	22.75	22.11	22.35	22.22
Fe <sub>2</sub> O <sub>3</sub>	==	2.56	2.50	2.71	0.70
FeO	==	5.43	5.43	5.43	5.30
(NiCo) O }	==	0.30 }	0.41 }	0.26	0.11
MnO }					0.17
MgO	==	28.47	28.34	27.73	30.99
Ignition	==	13.80	14.50	14.36	11.63
		<hr/>	<hr/>	<hr/>	<hr/>
		100.87	100.42	100.01	100.60

Particular attention was paid to the state of oxidation in which the iron exists; the ferric oxide is not due, as Prof. Leeds suggests, to a superficial oxidation of some of the ferrous oxide in the mineral, but is an essential constituent of the chlorites, and its presence makes a considerable difference in the relative proportions of the protoxides and sesquioxides.

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O of the analyses of chlorites, above given, is as follows :

c1	==	3.50	:	3	:	4.40	:	3.09
c2	==	3.50	:	3	:	4.40	:	3.08
c3*	==	3.83	:	3	:	4.78	:	3.19
d1	==	3.66	:	3	:	4.20	:	3.55
d2	==	3.43	:	3	:	3.95	:	3.50
d3	==	3.30	:	3	:	3.87	:	3.41
d4	==	3.84	:	3	:	4.65	:	2.93

This is nearest to 7 : 6 : 8 : 6, which would correspond with the formula suggested by Rammelsberg :



All these chlorites belong to the species, which was called ripidolite by G. Rose, but which is now distinguished by Dana as prochlorite.

\* Besides the printer's mistake in Prof. Leeds oxygen ratio, I have corrected it in accordance with my views about the state of oxidation of the iron.

Besides the jeffersite there appear to be other products of the alteration of chlorite, at the Culsagee Mine, Nos. 22 and 23, which appear to be new.

### 22. KERRITE (a new mineral).

It consists of innumerable fine scales, which under the microscope do not present a definite shape. They are very soft. Sp. Gr. = 2.303, Chatard. Their color is pale greenish-yellow with tint of brown; their lustre is pearly.

When heated they exfoliate, but not as much as jeffersite; B. B. melts to a white enamel. Chlorhydric acid decomposes it easily with separation of silicic acid in pearly scales. No corundum has been found in the scaly aggregates, but sometimes plates of green chlorite are intermixed with it. It is named in honor of Prof. W. C. Kerr, State Geologist of North Carolina.

It was analyzed by Mr. Thos. M. Chatard with material, which was examined under the microscope and apparently perfectly pure. He found:

				Mean.		Oxygen.
SiO <sub>2</sub>	=	38.31	38.26	38.29		20.42
Al <sub>2</sub> O <sub>3</sub>	=	11.41	11.42	11.41	5.32	} 5.91
Fe <sub>2</sub> O <sub>3</sub>	=	1.93	1.97	1.95	0.59	
FeO	=	0.32	0.32	0.32	0.07	} 10.66
(NiCo) O	=	0.29	0.22	0.25	0.05	
MgO	=	26.30	26.50	26.40	10.46	
Ignition	=	21.22	21.28	21.25		18.89
		<hr/>	<hr/>			
		99.78	99.97			

The average of the two analyses gave the ratio of oxygen of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O = 5.4 : 3 : 10.3 : 9.5, which is nearly = 6 : 3 : 10 : 10, represented by the formula :



### 23. MACONITE (a new species).

This is another scaly mineral, and closely resembles a fine scaly jeffersite. The scales are slightly harder than the last, and under the microscope they are also irregular. Sp. Gr. = 2.827, Chatard. They are dark brown, their lustre pearly inclining to submetallic. When heated, exfoliates largely and fuses with difficulty to a brown glass. Easily decomposed by chlorhydric acid with separation of silicic acid in pearly scales.

Contains numerous fragments of dark blueish-gray corundum, and microscopic apparently triclinic brilliant reddish-brown crystals which may be *sphene*. Name from Macon County, North Carolina.

Two analyses of apparently perfectly pure material were made by Mr.

Thos. M. Chatard. The alcalies in the second analysis were determined by myself.

			Mean.		Oxygen.	
SiO <sub>2</sub>	=	34.24	34.20	34.22		18.25
Al <sub>2</sub> O <sub>3</sub>		21.41	21.66	21.53	10.03	} 13.75
Fe <sub>2</sub> O <sub>3</sub>		12.28	12.54	12.41	3.72	
FeO		0.32	0.32	0.32	0.97	} 6.98
(NiCo) O		0.11	0.13	0.12	0.03	
MgO		14.30	14.61	14.46	5.78	} 6.98
Li <sub>2</sub> O		trace.	trace.	trace.		
Na <sub>2</sub> O		0.53	0.50	0.51	0.13	} 10.53
K <sub>2</sub> O		5.49	5.91	5.70	0.97	
Ignition		11.81	11.90	11.85		
Corundum		0.20	—	—		
		<hr/>	<hr/>			
		100.69	101.77			

The oxygen ratio of an average of the two analyses for RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O is = 1.52 : 3 : 3.98 : 2.3 = 3 : 6 : 8 : 5 nearly, giving the formula : 3 RO, 2 SiO<sub>2</sub> + 2 (R<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>) + 5 H<sub>2</sub>O.

About one-sixth of RO are alcalies R<sub>2</sub>O.

#### 24. WILLCOXITE (a new species).

There is still another mineral which appears to be new. It consists of white and greenish-white or grayish-white scales of a pearly lustre, and much resembles talc. B. B. in thin splinters, it fuses with difficulty into a white enamel; colors the outer flame yellow. With chlorhydric acid decomposed with difficulty with separation of silicic acid in pearly scales. It occurs sparingly, and I have seen it only in connection with corundum as a result of its alteration. One specimen from Shooting Creek, Clay County, North Carolina, is a fragment of a semiglobular mass, which probably once consisted entirely of corundum and which now has a nucleus of white lamellar corundum, invested with the scaly mineral. The largest diameter of the specimen is two and a-half inches, and that of the core of corundum three-fourths of an inch.

It is named in honor of Col. Joseph Wilcox, who presented me with the specimen from Shooting Creek, and who possesses a still larger, but otherwise very similar one.

It is found more or less intermixed with white corundum at the Cul-lakenee Mine, in Clay County, and probably at the Culsagee Mine, in Macon County, if a specimen of a grayish and greenish-white scaly mineral with a nucleus of white corundum which I received from there, really comes from this locality.

Dr. Geo. A. Koenig furnished me with two analyses of this mineral (1) from material from the Shooting Creek specimen surrounding the nucleus

of corundum, the other (2) from a piece from the Cullakenee Mine, Clay County, North Carolina.

	1.	2	Mean.	Oxygen.	
SiO <sub>2</sub>	28.96	29.50	29.23	15.59	
Al <sub>2</sub> O <sub>3</sub>	37.49	37.56	37.52	17.48	} 17.88
Fe <sub>2</sub> O <sub>3</sub>	1.26	1.40	1.33	0.40	
FeO	2.44	2.38	2.41	0.54	} 9.53
MgO	17.35	17.20	17.28	6.91	
Li <sub>2</sub> O	trace.	trace.	trace.		} 9.53
Na <sub>2</sub> O	6.73	6.24	6.48	1.67	
K <sub>2</sub> O	2.46	2.42	2.44	0.41	
Ignition	4.00	3.32	3.66	3.20	
	100.69	100.02	100.35		

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O = 1 : 1.88 : 1.64 : 0.33, which is nearest to 6 : 12 : 10 : 2, which can be expressed by the formula : 3 (2 RO, SiO<sub>2</sub>) + 2 (2 R<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>) + 2 H<sub>2</sub>O.

About one-fifth of RO are alcalies R<sub>2</sub>O.

## 25. PATTERSONITE.

The chloritic mineral associated with the lesleyite at Unionville and described by J. Lea (*l. c.*) under the name of pattersonite, has been analyzed by S. P. Sharpless (*l. c.*) who determined, as he says, the potash by difference, and gives 11.35 per cent. of it. But (as Prof. Brush first pointed out) his analysis, exclusive of the potash, sums up only 78.64 per cent. A re-examination was therefore very desirable. Dr. J. Lea has very generously furnished for this purpose the material of this rare mineral, of which I have made the following analyses :

Sp. Gr. = 2.810.

	Nearly Pure.	Purest.			
SiO <sub>2</sub>	29.89	29.90	contains oxygen	15.95	
Al <sub>2</sub> O <sub>3</sub>	} 30.87	27.59	" "	12.86	} 13.80
Fe <sub>2</sub> O <sub>3</sub>		3.12	" "	0.94	
FeO	9.17	9.17	" "	2.04	} 9.43
MgO	17.53	17.10	" "	6.84	
Li <sub>2</sub> O	trace.	trace.			} 9.43
Na <sub>2</sub> O	0.83	0.58	" "	0.15	
K <sub>2</sub> O	2.41	2.33	" "	0.40	
Ignition	11.60	11.51	" "	10.23	
	102.30	101.30			

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O is = 2.05 : 3 : 3.47 : 2.22 = 6 : 9 : 10 : 6, corresponding with : 2 (3 RO, SiO<sub>2</sub>) + 3 (R<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>) + 6 H<sub>2</sub>O.

The oxygen ratio is very near that of thuringite, which is 1 : 1.5 : 1.5 : 1.

## 26. CHLORITOID.

This mineral has been observed at many of the corundum localities. It is associated with diaspore, mica and cyanite as Kassoibrod in the Ural; in Asia Minor with corundum, diaspore and margarite; at Chester, Massachusetts, with emery and diaspore. One specimen from Augusta County, Virginia, consists of chloritoid, damourite and grains of corundum; I found one little crystal in the washings of the soil from the Culsagee Mine. A very interesting occurrence is that in the pyrophyllite slates of Chatham County, North Carolina, where it occurs in minute shining scales of a dark blackish-green color disseminated through the white rock. With great difficulty I have selected a quantity of apparently pure material for analysis.

		Sp. Gr. = 3.353.		
SiO <sub>2</sub>	=	26.13	contains oxygen =	13.94
Al <sub>2</sub> O <sub>3</sub>		40.11		18.69
Fe <sub>2</sub> O <sub>3</sub>		3.44		1.03
FeO		23.01		5.11
MnO		trace.		
MgO		0.94		0.38
Ignition		6.91		6.14
		<hr style="width: 20%; margin: 0 auto;"/>		
		100.54		

The oxygen ratio of RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O is = 0.83 : 3 : 2.12 : 0.97 = 4 : 15 : 10 : 4, giving the formula : 4 RO, SiO<sub>2</sub> + 5 R<sub>2</sub>O<sub>3</sub>, 4 SiO<sub>2</sub> + 4 H<sub>2</sub>O, which corresponds closer to my analysis than the formula 4 RO, SiO<sub>2</sub> + 4 R<sub>2</sub>O<sub>3</sub>, 3 SiO<sub>2</sub>, which is generally given. However, there may have been a minute quantity of pyrophyllite in my material which might be the cause of this discrepancy.

## 27. MARGARITE.

This species had been known for a long time from one locality, Sterzing in Tyrol, but not until the almost simultaneous discovery of it in association with the corundum from Pennsylvania and North Carolina, by B. Silliman and with emery in Asia Minor and Greece by J. L. Smith, its importance became apparent. Since then it has been observed almost everywhere with corundum, but a great portion of the laminated varieties of damourite have been confounded with it; it so much resembles the latter in all its varieties, that the only safe way for distinction is by chemical analysis.

At Unionville, many of the corundum crystals have a coating of a soft mineral, and sometimes the whole mass of the crystals is converted into it; a qualitative analysis proved these coatings to be margarite. More fully investigated were the following varieties:

a. A part of a crystal, showing the basal plane *a*, and a pyramid, which seems to be  $\frac{1}{3}$  and consisting of a grayish-white soft mineral. To the naked eye it looks like an amorphous substance without lustre.

With a strong magnifying glass it is shown to be crystalline, and to consist of exceedingly minute scales with a pearly lustre, radiating from a nucleus of gray corundum, which occupies the centre of the crystal, so that the cryptocrystalline mineral has a somewhat fibrous (pseudofibrous) structure. On the outside of the mineral are small scales of damourite. I have made two analyses of the *purest* cryptocrystalline mineral, which closely corresponded, and of which I give below the mean result (*a1.*) For corroboration, I have made a third analysis of material, which was not as pure and contained a few scales of the damourite, the influence of which upon the analysis (*a2.*) will be noticed by the increased amounts of silicic acid and potash and a reduction in the quantity of lime.

*b.* A laminated white variety, having a very faint reddish tint, occurs rarely with the granular corundum recently discovered. It is associated with black tourmaline and forms a coating upon or small veins in the grayish-white corundum. The laminae are sometimes nearly one inch broad, but usually smaller. My analysis is given below (*b.*)

*c.* An aggregation of fine scales and laminae somewhat of a granular structure, also of a white color with a faint reddish hue, and associated with black tourmaline, appeared to be a mixture of margarite with corundum; on powdering, however, it was found to be almost free from the original mineral, which existed in it only in very minute grains. The carefully selected material was analyzed by Dr. G. A. Koenig (*c.*)

*d.* A massive apparently compact or finely granular variety, has lately been found with the granular corundum; strongly magnified it appears as an aggregate of very small scales; on one side they are bounded by an aggregate of larger scales, intermixed with chlorite. Its color is white, but there are many ferruginous brownish-yellow spots disseminated through the mass. The purest which could be selected was analyzed by myself (*d.*)

*e.* A compact variety, frequently containing fragments of unaltered corundum, has been analyzed by Mr. Thos. M. Chatard (*e.*) It has a grayish-white to brownish-white color, and breaks easily into angular fragments of one or two inches in size, which are generally coated with hydrated ferric and manganic oxides. The margarite itself shows under the microscope a cryptocrystalline structure, it has a slight waxy lustre.

*f.* The margarite, which was found associated with the boulder of blue corundum, near the French Broad River, Madison County (formerly Buncombe County), North Carolina, has been analyzed by B. Silliman (*f. c.*)

*g.* At the Culsagee Mine, North Carolina, margarite is a rare mineral. I have noticed it only in a rock, consisting of a feldspathic mineral, mostly decomposed into kaolinite, a greenish hornblende, and small quantities of a chloritic mineral, the whole mass intermixed with white and pink corundum and laminae of margarite. (I have not mentioned this rock above, because its occurrence seems to be local and I have no further information about it).



The pure margarite is white and has a pearly lustre. It has been analyzed by myself (*g1*) and Mr. Chatard (*g2*).

*h.* The most beautiful varieties of margarite occur at the Cullakenee Mine, North Carolina. Here it occurs in groups of laminated crystals, distinctly showing the lateral planes of the same. The largest group, which I have seen is two inches long, one and a-half wide and five-eighths inches thick. The color of the basal cleavage planes is brownish-white, but after treatment with dilute chlorhydric acid, which removes a thin coating of ferric hydrate, the color is slightly pinkish-white with a hue of silver-gray; the lateral planes have a darker color.

Tourmaline is sometimes inclosed between the laminae, and they are in some of the specimens intersected by crystals of an unknown mineral, to which I have already alluded. The most important association, however, are the nuclei of corundum, completely invested by the groups of laminated margarite. There are also scales of a bronze or brownish-yellow mineral, probably the result of the alteration of margarite, which I shall describe farther on as dudleyite. Mr. T. M. Chatard has analyzed this variety (*h1*).

Another from the same locality occurs as the product of the change of grayish-white corundum. It is frequently associated with zoisite, and intermixed with corundum in the form of broad laminae of a delicate pink color. I have made an analysis of it (see *h2* below).

Associated with the mineral which I described as willcoxite, rarely occurs a somewhat fibrous variety made up of microscopic scales of margarite of a pearly lustre. It resembles much the variety of damourite *e*, but was found by qualitative analysis to be margarite, containing a considerable quantity of lime, but no potash. It completely surrounds a mass of gray corundum.

Still another variety from the Cullakenee Mine is found in thin seams of a grayish-green color. When magnified, the mineral consists of an aggregate of minute pearly scales of a greenish-white and sea-green color. I give the analysis, which I made under *h3*.

*i.* Crystalline masses of gray corundum from near Penland's, Clay County, North Carolina, which I have examined, are coated with a cryptocrystalline pseudofibrous mineral of a white and yellowish-white color, which gave by qualitative analysis, a considerable quantity of lime, but no potash, and which therefore appears to be margarite.

A similar coating containing lime, is sometimes found on the blue crystals of corundum from Crowder's Mountain, Gaston County, North Carolina.

These coatings on corundum crystals, which have been observed frequently, are sometimes not thicker than a thick varnish, sometimes the whole crystal has been altered, leaving not even a core of the original mineral.

*k.* I have above alluded to the kidney-shaped and irregular masses from Gainesville, Hall County, Georgia, which consist of a nucleus of

corundum completely surrounded by margarite, and also by an earthy mineral with veins of foliated margarite through it. The margarite in contact with the grayish-white or pinkish corundum, is sometimes cryptocrystalline, pseudofibrous, but generally in aggregates of small pearly-white scales, of which I have made an analysis (*k1*). In the yellowish flesh colored mineral, the margarite is found in small veins consisting of pearly greenish-white scales, much resembling talc. My analysis (*k2*) proved them to be margarite.

*l*. A beautiful white variety of broadly laminated margarite completely enveloping masses of cleavable corundum, has lately been discovered at Dudleyville, Alabama. The laminae are sometimes two inches broad. I have analyzed it with the results given under *l*. This margarite appears to change into a bronze-colored or brownish-yellow mineral, of which I shall give a description below.

The following are the results of the analyses :

Sp. Gr.	=	a1.	a2.	b.	c.
SiO <sub>2</sub>		32.19	33.46	30.70	31.48
Al <sub>2</sub> O <sub>3</sub>		49.62	—	49.33	49.01
FeO		0.91	—	0.39	0.52
MgO		0.41	—	0.76	0.54
CaO		7.81	7.05	11.86	10.70
Li <sub>2</sub> O		trace.	—	0.36	
Na <sub>2</sub> O		4.78	4.41	0.96	1.34
K <sub>2</sub> O		0.57	1.02	0.65	
Ignition		3.93	4.94	5.91	3.94
Corundum		—	—	—	2.00
		<hr/>	<hr/>	<hr/>	<hr/>
		100.22		100.92	99.54

Sp. Gr.	=	d.	e.	g1.	g2.	h1.
SiO <sub>2</sub>		30.45	31.29	28.11	28.80	29.34
Al <sub>2</sub> O <sub>3</sub>		50.86	47.24	49.16	49.57	48.73
FeO		0.42	0.85	0.43	0.34	0.78
MgO		0.37	0.88	0.45	0.75	0.78
CaO		12.13	10.86	11.08	11.33	11.32
Li <sub>2</sub> O		trace.	trace.	0.45	not det'd.	trace.
Na <sub>2</sub> O		1.72	2.66	0.67	"	2.61
K <sub>2</sub> O		0.25	0.24	0.22	"	0.10
Ignition		4.48	5.92	6.43	6.64	6.55
Corundum		trace.	—	3.31	—	—
		<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
		100.68	99.94	100.31		100.21

Sp. Gr.	=	<i>h</i> 2.	<i>h</i> 3.	<i>k</i> 1.	<i>k</i> 2.	<i>l</i> .
		3.055	3.064	—	3.004	3.085
SiO <sub>2</sub>		30.72	29.63	33.21	32.15	28.71
Al <sub>2</sub> O <sub>3</sub>		49.83	51.19	48.55	49.28	52.44
Cr <sub>2</sub> O <sub>3</sub>		—	0.13	—	—	—
FeO		0.84	0.59	0.46	0.57	0.39
MgO		0.73	1.09	0.39	0.63	0.74
CaO		10.84	11.28	10.04	11.09	11.52
Li <sub>2</sub> O		trace.	—	trace.	trace.	0.38
Na <sub>2</sub> O		2.19	1.22	1.64	1.18	0.67
K <sub>2</sub> O		0.26	0.20	1.39	1.04	0.20
Ignition		6.21	4.73	4.59	4.16	5.40
Corundum		—	—	trace.	—	—
		<hr/> 101.65	<hr/> 100.06	<hr/> 100.27	<hr/> 100.14	<hr/> 100.45

It will be observed that in some of the margarites a considerable quantity of alcalies (R<sub>2</sub>O), especially soda, replaces lime. This is especially the case with *o*1, in which one-third, and *e* and *h*1 and 2, in which about one-sixth of the lime is thus replaced.

Although many of these analyses were made only for the purpose of determining the species—in general they agree well with the established oxygen ratio for RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O = 1 : 6 : 4 : 1.

Some contain a larger quantity of water.

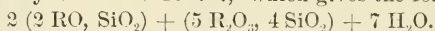
I must not omit to notice here the description of a very important specimen which J. L. Smith (*l. c.*) gives in his memoir on emery: *A nodule, containing emery in the centre, with two concentric layers, the inner of chloritoid, the outer of emerylite (margarite).* In other words a pseudo-morph of chloritoid and margarite after corundum!

## 28. EARTHY MINERAL FROM GAINESVILLE, GEORGIA.

Associated with and forming the matrix of some of the Gainesville margarite and resulting, like the latter, from the alteration of corundum is an earthy mineral, of which I have made an analysis. Its structure is finely granular; it is soft, but contains some hard particles which appear to be quartz. Its color is between isabel-yellow and flesh-color. Very minute particles of margarite are intermixed with it.

Sp. Gr.	=	2.851.	
Quartz	=	2.17	
SiO <sub>2</sub>	=	28.84	contains oxygen 15.38
Al <sub>2</sub> O <sub>3</sub>	=	39.65	18.48 } 19.12
Fe <sub>2</sub> O <sub>3</sub>	=	2.12	0.64 }
MgO	=	1.26	0.50 }
CaO	=	14.75	4.21 }
Na <sub>2</sub> O	=	0.48	0.12 }
K <sub>2</sub> O	=	1.60	0.27 }
Ignition	=	10.41	9.25 }
		<hr/> 101.28	

The oxygen ratio of  $RO : R_2O_3 : SiO_2 : H_2O = 1 : 3.75 : 3.01 : 1.8$ , or very nearly  $4 \cdot 15 : 12 : 7$ , which gives the formula :



Although the material was not quite pure, containing a very minute quantity of margarite, I wish to put this analysis on record, believing the mineral to be new, and wishing that it may be found in a state of greater purity.

### 29. DUDLEYITE (a new species).

At the Cullakenee Mine, but in larger quantity with the margarite of Dudleyville, Alabama, a soft bronze or brownish-yellow mineral is found, which is probably the result of the alteration of margarite and still retains its form; lustre pearly. When heated, it exfoliates very slightly and then melts with difficulty into a brownish-yellow plebby mass.

With chlorhydric acid decomposed easily with separation of silicic acid in pearly scales. It is named after the locality, Dudleyville, Alabama.

The analysis gave :

SiO <sub>2</sub>	=	32.42	contains oxygen	17.29	
Al <sub>2</sub> O <sub>3</sub>		28.42		13.24	} 14.74
Fe <sub>2</sub> O <sub>3</sub>		4.99		1.50	
FeO		1.72		0.38	} 7.71
MgO		16.87		6.75	
Li <sub>2</sub> O		0.19		0.10	
Na <sub>2</sub> O		1.52		0.39	
K <sub>2</sub> O		0.56		0.09	
Ignition		13.43		11.94	
		<hr/>			
		100.12			

The oxygen ratio for  $RO : R_2O_3 : SiO_2 : H_2O$  is  $= 1 : 1.91 : 2.24 : 1.55$ , which is very near  $6 : 12 : 14 : 10$ , giving the formula :  $2 (3 RO, 2 SiO_2) + (4 R_2O_3, 3 SiO_2) + 10 H_2O$ .

### 30. LAZULITE.

In mentioning the alteration of the corundum of Crowder's and Clubb's Mountains, Gaston County, North Carolina, I observed that in all these localities, and others which I considered as analogous, *lazulite* was one of the results of alteration.

I have seen specimens from the Gaston County localities which were mixtures of lazulite and damourite, and, what is very significant, lazulite, which inclosed crystals of rutile, the constant associate of the corundum at these localities.

Although not in accordance with the views of modern chemistry, I hope that I will be justified in having attempted to give the composition of these minerals in formulæ, which, as we once thought, would express an idea of the rational composition of the species. I do not intend to discuss their merits, I will even admit that such formulæ state a great

deal more than what with our knowledge of the subject, we have a right to express. Yet there are so many geologists and mineralogists, who have familiarized themselves with this mode of expression, that I thought it an injustice to them to give merely the empirical composition.

After having thus given the above data, the conclusions arrived at by this investigation are :

That, at the great period when the chromiferous chrysolite beds (in part subsequently altered into serpentine, etc.) were deposited, a large quantity of alumina was separated which formed beds of corundum ;

That, this corundum has subsequently been acted upon and thus been changed into various minerals, such as spinel, fibrolite, cyanite, and perhaps into some varieties of feldspar, also into tourmaline, damourite, chlorite and margarite ;

That, a part of the products of the alteration of corundum still exists in the form of large beds of mica-(damourite) and chlorite-slates or schists ;

That, another part has been farther altered and converted into other minerals and rocks, such as pyrophyllite, paragonite, beauxite, lazulite, etc.

The question has often been asked me, how I could explain these wonderful changes which have taken place with a substance so absolutely insoluble as corundum? My answer is that I know nothing about it. I have in this whole investigation carefully avoided making any statements which are not based upon undeniable facts ; in a few instances only, where the facts were very strong in my favor, I have allowed myself to judge from analogy.

Mr. S. P. Sharpless is probably correct in his supposition that corundum has been altered into lesleyite and pattersonite by the action upon it of water containing alkaline silicates. Such a view is very plausible, especially if we add an elevated temperature and great pressure. I have tried a number of experiments in this direction. I have put corundum reduced to an impalpable powder, and subsequently boiled out with chlorhydric acid and washed with water, into a glass tube with a solution of potassic silicate, and after sealing it have exposed it to a temperature, which was gradually increased to about 250° C. With one exception, all my tubes burst before the alkaline silicate had time to act upon the corundum. In this one case the tube stood for about three days and nights, before it exploded. The scales of the mineral substance, which came from the tube were carefully collected, washed out and then treated with dilute chlorhydric acid and evaporated to dryness, the residue moistened with chlorhydric acid, the mass extracted by water. The clear liquid gave with ammoniac hydrate a trace of a flocculent precipitate, which appeared to be alumina. The quantity was too small, however, to place any value upon this experiment. It may be well to mention in this connection that under pressure and reduced to a fine powder, corundum dis-

solves with considerable facility in dilute sulphuric acid, as I have already stated above.

I hope that the time may soon arrive when we shall have a clear insight into the alterations of corundum, which I have above described. At present we have no facts upon which a tenable theory could be built.

And this finishes my task. I have devoted to it my leisure hours for over two years. Nobody can be more aware of the many imperfections of this investigation, but I hope that it will be taken into consideration that I have labored under very great disadvantages. I had for consultation neither a collection to compare my specimens with those from other parts of the world, nor a library of sufficient completeness. All that I have done, I have done with my own labor and the assistance of many kind friends, to whom I am under great obligations; of the many who helped with specimens, etc., I will especially mention Rev. Dr. E. R. Beadle, Prof. G. J. Brush, Dr. Isaac Lea, Dr. Joseph Leidy, Rev. C. D. Smith, of Franklin, North Carolina; Prof. E. A. Smith, of Tuscaloosa, Alabama, and Col. Joseph Willcox; the greatest gratitude I owe to my assistants, Dr. Geo. A. Koenig and Thos. M. Chatard, S. B., for the many valuable analyses which they made, and which alone have enabled me to finish this work in this comparatively short time.

University of Pennsylvania, August 18, 1873.

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#### POSTSCRIPT.

Since writing the above, an article has appeared in the September number of the American Journal of Science and Arts, entitled "Notes on the Corundum of North Carolina, etc., by J. Lawrence Smith, Louisville, Kentucky," which contains analyses of a few species, discussed in my paper.

There are a few points to which I wish to call attention.

Under "*zoisite*," Dr. Smith gives analyses of two minerals, which, in my opinion, do not belong to this species. The "*light green*," analyzed by Tho. M. Chatard and described as Smaragdite(?) (Kokscharoffite), is probably an aluminous hornblende (?), the black variety is evidently the same mineral, containing, however, as proved by Dr. Smith's analysis, a part of the alumina replaced by ferric oxide. The *zoisite* from Cullakee is *always white* with only a *slight grayish* or *greenish tint*.

The granular "*andesite*" gives, according to his analysis, the oxygen ratio 0.85 : 3 : 9.09, which is very near = 1 : 3 : 9, placing this mineral, like that from Chester, Massachusetts, under *oligoclase*.

Philadelphia, August 28, 1873.